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WELDING

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Official Publication of the American Welding Society

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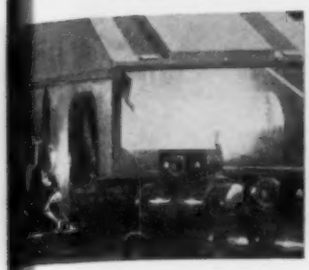

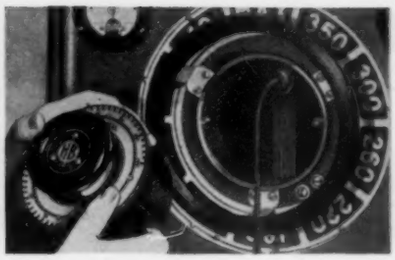

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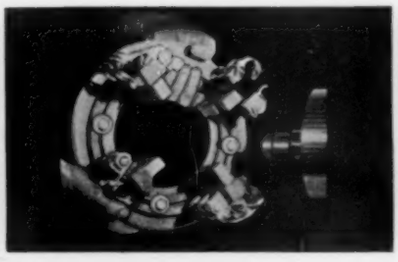

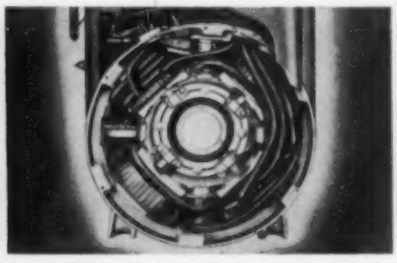

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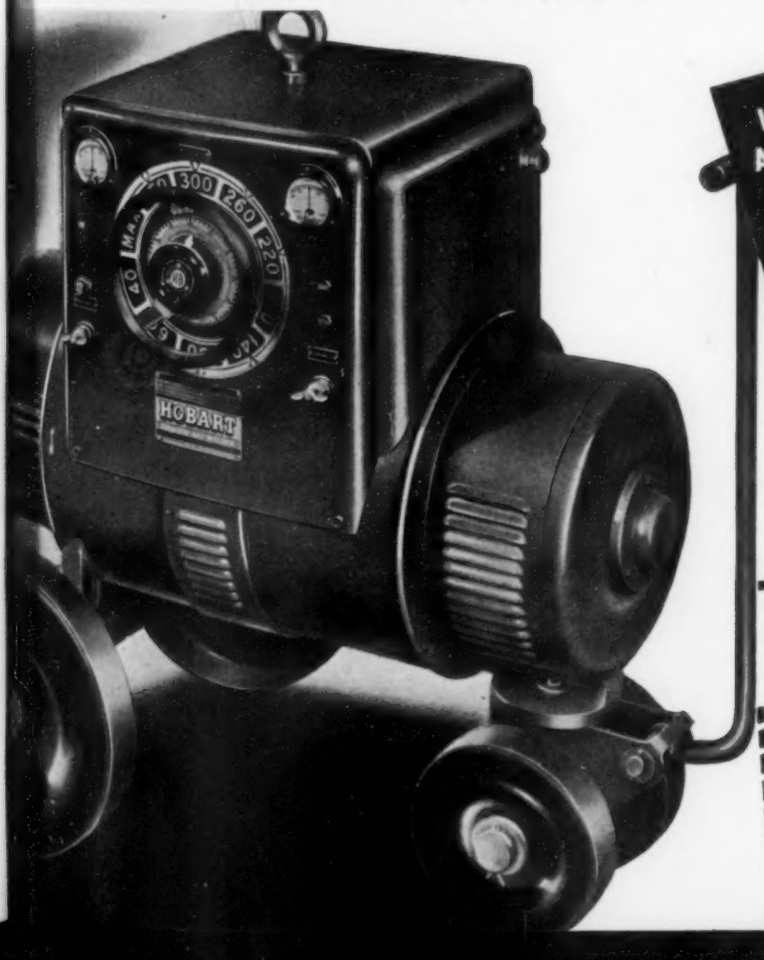

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Published for the Advancement of the Science and Art of Welding

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Welding Journal

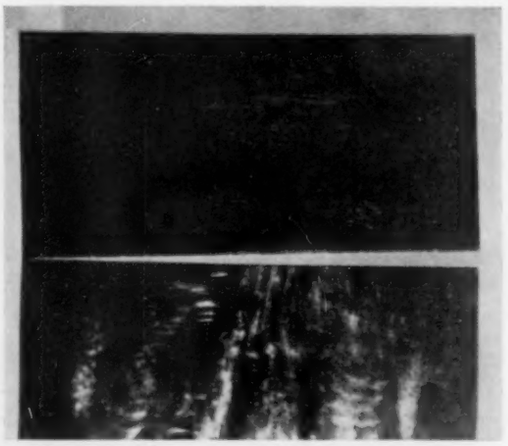
VOLUME 19, No. 8 AUGUST 1940

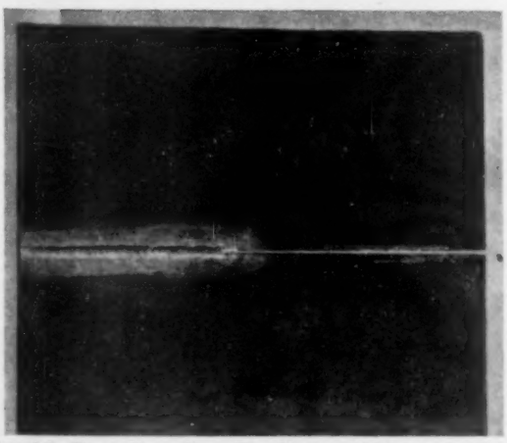
JIGS AND FIXTURES FOR Oxyacetylene Welding*

By JOHN HAYDOCK†

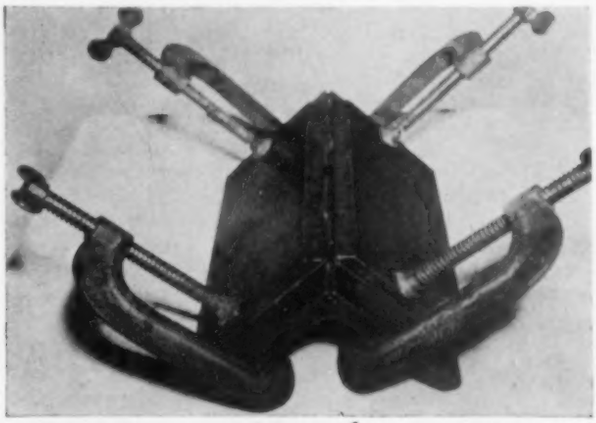
WHEN a welder comes up against a job that needs a jig of some kind, he is often able to make one himself. In jobbing work, particularly, he frequently takes his torch and a few pieces of scrap metal to rig up something that will serve his purpose.

This may not be engineering, but it saves the time that would have been necessary to get a jig designed in the Engineering Department. The jig may not look like much, when it is finished, but often it enables the welder to turn out a satisfactory job without bothering anybody else.





Figs. 1 and 2—These Views Show Two Sheets of Metal in the Process of Being Welded Together. As Welding Progresses Along a Straight Seam the Edges of the Metal Will First Spread Slightly Because of Expansion, and Then Draw Together as the Weld Cools. Unless This Motion Is Controlled, the Two Edges May Overlap Before the Weld Is Completed. To Allow for Contraction, a Wedge-Shaped Gap Is Allowed Between the Two Sheets. The Welder Can Often Approximate the Spacing from His Own Experience. This Varies with the Thickness of the Sheet and with the Length of the Seam. A Rule-of-Thumb Approximation Is to Allow Spacing Equal to the Thickness of the Sheet for Every Foot of Weld Length. The Sheet Movement and Space Allowance Is Held to a Minimum by Welding as Rapidly as Good Practice Permits. In Designing Welding Jigs, It Is Important to Keep This Movement of the Metal in Mind



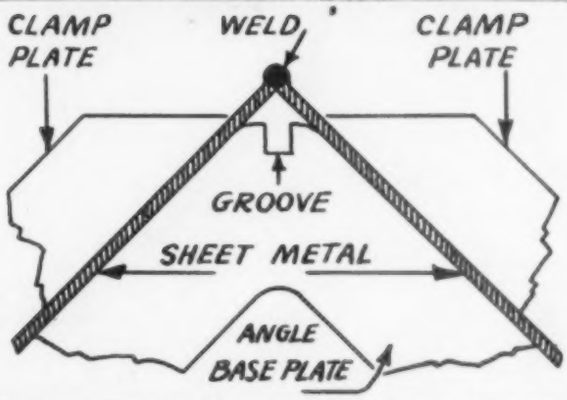


Fig. 3—For a Corner Weld a Simple Angle Iron with the Corner Cut Away May Be Used for a Base Plate. The Sheets to Be Welded Are Placed with the Seam Directly Over the Groove in the Base Plate. The Clamping Plates Are Beveled as with a Flat Weld to Give the Operator a Good Chance to Manipulate His Torch During the Operation

In the machine shop, practically all jigs and fixtures today are designed by tool engineers. A man operating a milling machine or boring mill is usually not in a position to make his own fixtures, as he must depend on someone else for his material and his designs. On the other hand the welder has an assembly tool in his torch. It is always handy and very often he is able to put something together without saying anything to anybody about it.

* Presented before the 40th Annual Convention, International Acetylene Association, Milwaukee, Wisconsin, April 10, 11 and 12, 1940.

† Managing Editor, *American Machinist*, New York, N. Y.

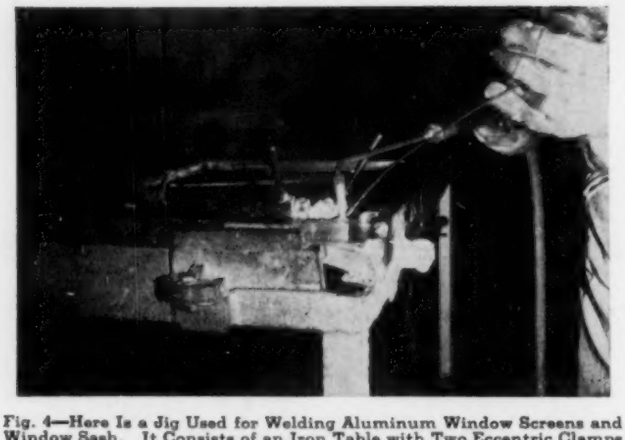


Fig. 4—Here Is a Jig Used for Welding Aluminum Window Screens and Window Sash. It Consists of an Iron Table with Two Eccentric Clamps at the Corner. The Table Has Been Cut Away to Allow Room for the Welding Torch. The Sides of the Table at the Corner Are Squared Off to Hold the Frame in Proper Position. These Frames Are First Tack-Welded on a Pair of These Tables with the Welder and a Helper Working Together. The Welder Tacks One Corner, While the Helper Sets Up Another Frame in the Next Table So That the Torch Is Kept in Play Almost Continuously

Sometimes this is an advantage, and sometimes it is not. If the welder is intelligent and understands the basic principles of jig design, he can usually do a pretty good job. On the other hand, where production quantities are involved, a well-engineered jig is often worth the additional time and trouble needed to lay it out on paper. This also holds true for general purpose jigs so designed that they can be used on a wide variety of short-run work.

Letting the operator improvise his own jigs may at first glance seem to be the easiest way to do it. It must be remembered, however, that when he is making jigs his time is lost for productive work. He may spend a good deal of time looking around for suitable pieces of scrap and then fabricate something that does not work out as he expected.

The ultimate solution is, of course, to do the planning for the man at the torch. On production work especially, problems of welded fabrication should be anticipated with all necessary jigs drawn up and built before the job is started. Good planning of this kind will save time and money in the long run. This is not to say that the improvised jig should not be used in the job shop, as unforeseen difficulties arise.

Attempts have been made in the past to distinguish between the terms "jig" and "fixture" as applied to welding. These terms are borrowed from the machine shop, but even here the distinction is far from definite. We can make definitions, but there will be many borderline cases and many exceptions. What is called a jig in one shop is a fixture in another. In welding, there is even less excuse for the two terms than in the machine shop. So, to simplify matters for the purpose of this paper, all such devices will be called jigs.

Having thus easily disposed of fixtures, what is a jig? It is a device designed to facilitate the process of welding and to improve the quality of the product by holding the work pieces in proper relationship, by positioning them to afford ready access to the welded sections, and by limiting the adverse effects of heating and cooling.

Welding jigs necessarily differ greatly from those used in the machine shop. One big difference is the change in temperature with its resultant expansion and contraction. Welded work is usually bulkier and very often flimsier than that found in the machine shop.

The subject of oxyacetylene welding jigs will be considered in two steps: (*a*) the basic requirements involved, and (*b*) the application of these principles as they are worked out in practice.

The basic requirements of a well-designed welding jig may be listed as follows:

1. *Simplicity.*—This is the basic of all good design. If a jig is simple it will be easy to make and easy to manipulate. In this field of work there is no excuse for complicated designs.

2. *Convenience.*—The work must be held in position to make a good weld. Downhand welding is usually easier, but it is not always possible to get all surfaces in this position. Moving jigs are often used to bring various parts of the work piece successively into handy reach of the operator. The motion of such jigs is supplied by hand in some cases, and by power in others.

3. *Visibility.*—Besides getting at the work, the welder must be able to see it clearly, if he is to turn out a high quality product. All jig designs must meet this requirement if the jig is to be of any practical use.

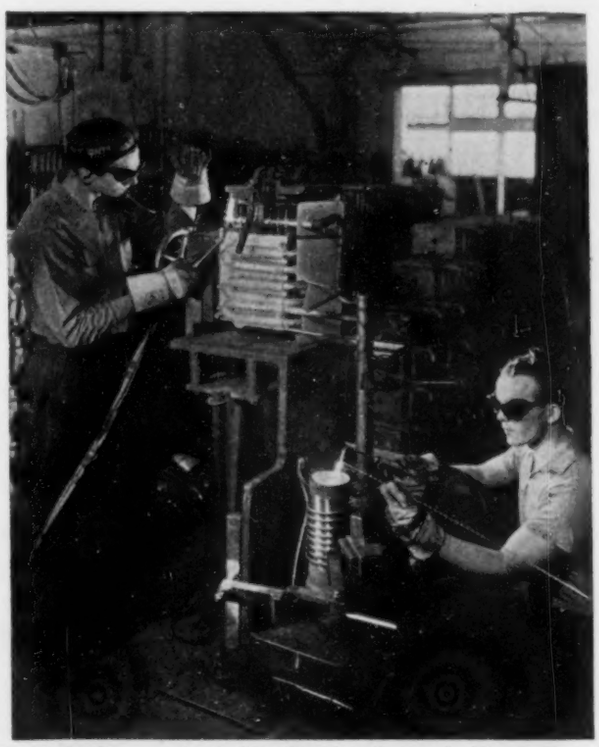


Fig. 5—The Purpose of a Jig Like This Is to Locate the Various Parts of a More Complicated Assembly While They Are Being Welded Together. This Particular Jig Is Used by Serval for Connecting the Evaporator with the Gas Heat Exchanger and the Absorber. Note the Built-In Brackets for Holding Welding Rods. The Cylindrical Parts of the Assembly Are Held in V-Blocks by Means of Quick-Acting Toggle Clamps

Consequently, all gripping plates or brackets must be placed so they will not interfere with the operator's vision.

4. *Rigidity.*—Like all jigs the welding jig must be strong enough to withstand deflection, or at least reflection beyond allowable limits. It should be remembered, however, that for thin gages of metal, it is necessary to allow slippage of the stock rather than to hold it rigidly.

5. *Durability.*—Jig designs for repetitive work must have wear surfaces that will stand up in usage. Where the jig is made for a single job or for a short run of work, this factor is naturally of less consequence.

6. *Heat Control.*—A welding jig must be able to carry away the heat from the torch and in addition hold the work so that it will not buckle or overlap. It is well known that as the welded metal cools, contraction

sets in. If a long seam is welded in light gage sheets, it is necessary to start the welds with the two edges at a slight angle. Then, as the weld progresses, the sheets will be brought together without overlapping. This contraction requires some motion in the position of the sheets and it is necessary to provide for slippage in the clamping members. In some jigs a spacing piece is used which is moved along as the weld progresses to keep the two edges proper distance apart. In jig design it should always be remembered that the clamping surfaces act as chills which aid the work piece itself in conducting heat away from the weld. Sometimes the jig

Fig. 6—An Example of a Power-Driven Operation Is This Horn-Type Jig Used for Welding the Seam on a Washing Machine Tub. The Formed Sheet Is Clamped on the Horn While the Welding Tip Is Fed Automatically Along the Seam. In This Case the Jig Itself Is Stationary, But the Part Is Moved Automatically

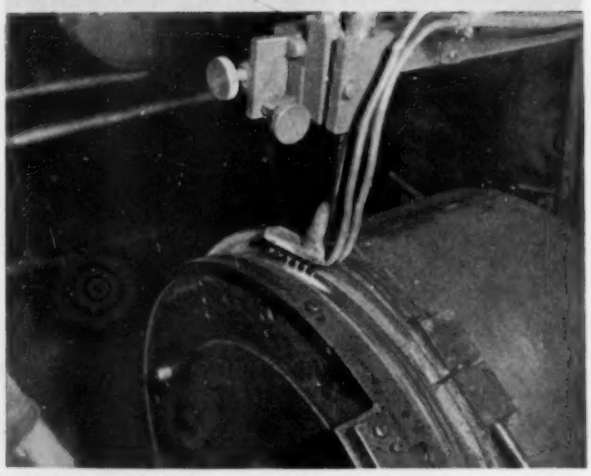


Fig. 7—A Close-Up of This Same Jig Shows the Details of the Clamps. A Roller Follows the Torch to Keep the Metal from Buckling During the Process of Welding

is water cooled or provided with copper inserts to speed up this process. However, the chilling surfaces should not be so close to the weld that they will interfere with complete fusion.

7. *Protection of Work.*—On some work, particularly on aluminum and stainless steel sheets, it is important not to mar the surface. For this reason, jigs must be designed so that the clamping fingers will hold the work without scoring it. Soft pads of asbestos or other material are used to protect the work in some instances.

8. *Clamping Pressures.*—This requirement is closely associated with heat control and protection of the work. A few welding engineers have gone so far as to figure

Fig. 8—This Jig Is Used for Welding Hoes. By Means of It the Operator Can Turn Out 190 to 200 Pieces an Hour or an Average of More Than Three per Minute. The Job Is to Bronze Weld an 0.20 C Steel Shank to an 0.40 C Steel Blade

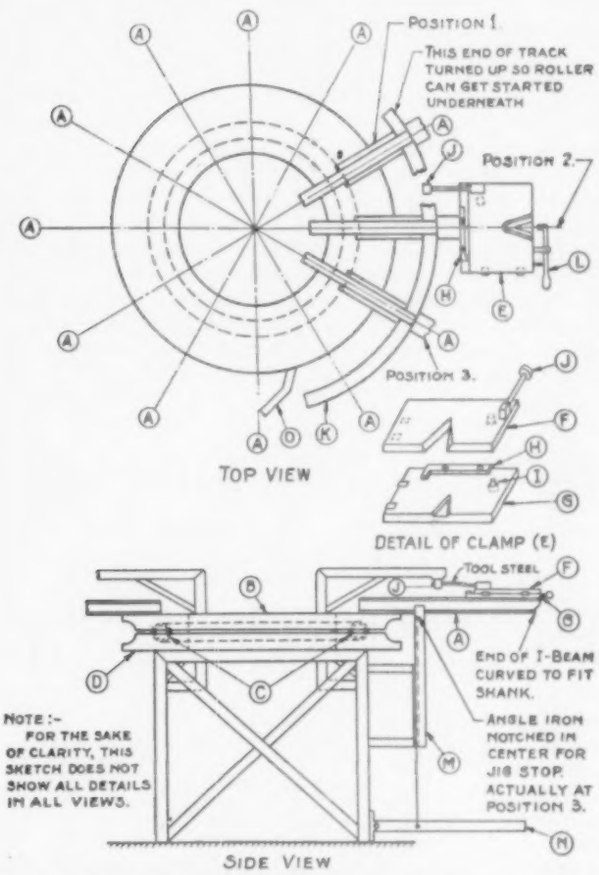

POSITION 1.
THIS END OF TRACK TURNED UP SO ROLLER CAN GET STARTED UNDERNEATH
POSITION 2.
POSITION 3.
TOP VIEW
DETAIL OF CLAMP (E)
TOOL STEEL
END OF I-BEAM CURVED TO FIT SHANK.
ANGLE IRON NOTCHED IN CENTER FOR JIG STOP. ACTUALLY AT POSITION 3.
NOTE:- FOR THE SAKE OF CLARITY, THIS SKETCH DOES NOT SHOW ALL DETAILS IN ALL VIEWS.
SIDE VIEW

Fig. 9—Welding Is Performed by an Operator and a Helper. The Helper at Position 1 Puts the Parts of the Hoe Into the Jig, While the Operator at Position 3 Bronze-Welds the Joint. At Position 2 the Jig Comes Under an Oxyacetylene Flame Which Strikes the Joint and Preheats the Metal. When the Joint Is Finished the Operator Releases the Stop by Depressing a Foot-Pedal and Rotates the Jig Arm Into the Next Position. The Stop Then Comes in Line with a Recess to Lock the Jig While the Welding Is Being Done. An Angle Iron Is Placed So That It Pushes the Finished Piece Out of the Jig After the Clamp Has Passed Beyond the Overhead Track and Is Released

Fig. 10—This Jig Was Designed for Bronze-Welding Sheet-Metal Fan Blades to a Steel Hub. The Work Is First Pressed Together and Then Fed by Hand on a Track Above Which Are Ten Equally Spaced Fingers. By Means of a Cam Operated Mechanism These Fingers Are Made to Push the Blades Along, Then Lift Up and Return to Their Original Position

deflection in the jig base and in the clamping fingers to produce excellent results. More often the clamping pressure is arrived at by a cut-and-try method, or on the basis of past experience. A good workable solution of this question has much to do with the success of the jig.

9. *Cost.*—The cost of welding jigs must be considered on the basis of that of any piece of new equipment. An estimate should be made of the time saved per piece, the number of pieces to be made, and the possible future use of the jig. Balanced against this is the cost of the jig itself. In short, no jig is justified unless it will pay for itself within a reasonable time. However, sometimes jigs are necessary in order to get the job done at all, or in order to hold it to specifications. Where the quality factor dictates the use of a jig, there is no alternative but to use one. When figuring on exacting jobs, the cost of welding jigs should be included along with production costs in arriving at the final estimate.

10. *Storage Facilities.*—A shop using a lot of jigs must figure on storage space. Otherwise it will be crowded with bulky units, used only occasionally, causing considerable inconvenience. With a little ingenuity, a great many jigs can be designed so they can be dismantled into relatively flat units and put away without taking up much room.

So much for the general considerations of welding jig design. The jigs themselves may be roughly divided into three classes; stationary jigs, hand-operated jigs and power-operated jigs. The simplest jigs are usually made up of structural shapes, together with C-clamps. Such clamps are cheap to use because they can be employed over and over again on different jobs, but they are not quick operating and consequently do not afford the best solution on production runs. Toggle clamps are quick acting and when properly designed will exert close control of pressure. Spring clamps, wedges, H-clamps, knobs and bolts are some of the common means of holding work in place. Each type must be considered in connection with a particular job.

Hand-operated jigs range all the way from a simple mandrel on which the work is revolved to some extremely complicated devices. Some of the simpler types consist of the horn jigs for cylindrical work, turntables, trunnions, face plates and spiders for holding the work internally.

Power either electric or pneumatic, is frequently applied to the same kind of jig that is hand-operated in its simpler form. The application of power is always a question of judging between increased production and increased cost of the jig. Power-operated jigs are becoming more popular as welding is used in an ever widening field and on increased sizes of production lots. Power may be applied merely to clamp the work in place and to release it after the welding has been completed; or it may be used to move the work, either intermittently or continuously, as the welding operation progresses. In such cases it greatly expedites the operation by giving an opportunity for almost continuous welding. Power clamping removes the human element in setting up a job by eliminating variations in clamping pressure.

The illustrations show how the principles of welding jig design are applied and how the principles pointed out may be worked to advantage in actual practice.

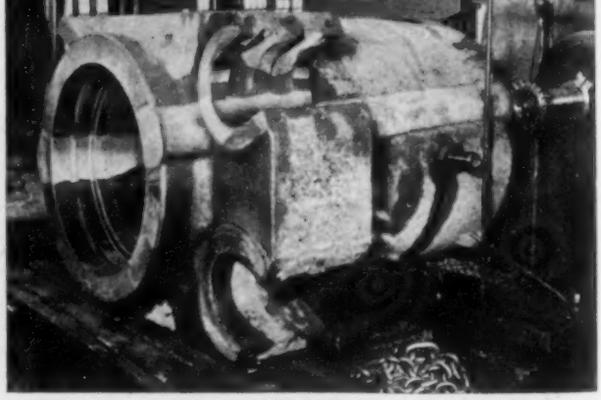
Thermit Weld Saves Extruding Press Cylinder

By M. L. SMITH

PRODUCTION of an important item in a large rubber factory was cut in half this winter when one of two large, cast-steel cylinders, of the type used in extruding lead castings on rubber hose and telephone cables, failed. Interruption to production schedules was avoided, however, by repairing the cylinder promptly with Thermit welding.

Weighing slightly more than 25 tons, the repaired cylinder is 77½ in. high, has an inside diameter of 30 in. and a wall thickness varying from 11 in. to 20 in. The thickness through the base is 14 in. at the thinnest part. Fracture was complete, the cylinder breaking into two sections, one of which was slightly larger than the other.

About one week was required to make the Thermit weld, including lining up of the parts, repairing the edges of the break, building the mold, preheating, pouring the Thermit steel and allowing the pieces to cool. Five thousand lb. of Thermit were used in making the repair and about 70 barrels of molding sand.



Twenty-five Ton Cylinder Repaired by Thermit Welding, Machined and Ready to Be Replaced in Service

OXYACETYLENE WELDING OF Carbon-Molybdenum Steel Piping for High-Pressure, High-Temperature Service*

Part I—Laboratory Development

By R. M. ROOKE† and F. C. SAACKE†

AS THE operating temperatures and pressures of steam power plants are raised, the problems of maintaining pipe lines pressure-tight with mechanical joints become more and more acute. Leakage and maintenance charges increase, and only by the construction of welded piping with the subsequent elimination of mechanical flanges can the power lines be made permanently and economically pressure tight. The application of welding to high pressure, high temperature power piping, besides eliminating leaks and maintenance charges, also makes the power lines less bulky, easier to lag with insulation and should permit of reductions in pipe wall thickness.

The application of fusion welding to the assembly of carbon-molybdenum steel pressure piping, however, has not been unattended with difficulties.

In the application of arc welding to the joining of carbon-molybdenum alloy steel pipe to eliminate porosity and secure grain refinement, it has been found preferable to deposit the weld metal in a large number of small beads.

With excessively localized contraction (steep temperature gradients), the carbon-molybdenum alloy steel tends to crack readily when under the customary degree of constraint that obtains in a multi-pass weld. To eliminate this tendency, the latest proposed revisions in Committee of the American Standards Association's code for pressure piping specify that "welded joints in carbon-molybdenum steel shall be preheated adjacent to the welding zone to a temperature of not less than 400° F. This preheating may be accomplished by any suitable method, providing that it is uniform and that the temperature is maintained during the actual welding operation."

Due to the nature of the carbon-molybdenum steel when welded and to the characteristics of the welding process, a typical welding procedure may specify the use of backing-rings, multi-pass welds with as many as 40 beads on $1^1/_4$-inch wall thicknesses, preheating for several hours, concurrent heating, postheating to raise the temperature to 1100°/1200° F., followed by stress relieving and controlled cooling.

The molybdenum bearing steels are characterized by a superior retention of strength at elevated temperatures. Consequently, the welding fabricator would prefer to simplify the methods of welding these steels rather than to change the analysis to a more easily welded material.

The oxyacetylene welding process has always been characterized by its simplicity of operation. No chipping, no peening, no backing or chill-rings are needed. Preheating is an inherent characteristic of the oxyacetylene welding procedure.

Chipping of oxyacetylene welds is not necessary as the oxides do not interfere with the deposition of subsequent layers of weld metal.

Peening reduces lateral residual tensile stresses, where lateral stresses have been set up by differential shrinkage across the weld caused by steep temperature gradients on cooling. With the gradual temperature gradients that obtain during the cooling of an oxyacetylene weld, peening is no longer necessary.

The nature of the oxyacetylene process provides sufficient control of the molten weld metal to allow butt joints to be made with full penetration without backing-rings. This characteristic has even been introduced into arc welding procedures by one fabricator who, in a paper read last year before the AMERICAN WELDING SOCIETY, stated that they had found backing-rings to be unnecessary if the first layer of weld metal were deposited in the root of the joint using the oxyacetylene process.

Preheating is used in arc welding to lessen the temperature gradients on cooling and thereby lower thermal stresses and prevent cracking. It is a practical necessity in oxyacetylene welding to preheat the base metal before starting to weld. Because of the lower temperature of the oxyacetylene flame, the temperature gradients on cooling are more gradual. Consequently, the thermal stresses are lower, and the gas weld shows little or no tendency to crack.

In spite of these inherent qualities, early attempts to oxyacetylene weld carbon-molybdenum steel piping were unsuccessful. Either the weld metal was not ductile enough or the yield point at elevated temperatures was too low. In one procedure, the pipe ends were upset so that the cross section was at least double the normal cross section of the pipe. These thickened pipe ends were then beveled and welded so that the stress in the weld metal would be no more than 50% of the stress in the pipe walls at the normal cross section. Naturally, it was felt that the weld metal tensile strengths at elevated temperatures need be no more than half the base metal strength. It is not practical, however, to necessitate costs of upsetting and to make 2-inch welds to join 1-inch wall thicknesses. Nor is it necessary to go to such

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† Apparatus Research and Development Department, Air Reduction Sales Company.

extremes. The oxyacetylene welding process is quite capable of producing strong, sound weld metal of high strength and ductility and of an analysis similar to that of the base metal.

The proper application of oxyacetylene welding, however, requires a knowledge of three variables, namely, the proper welding rod, welding methods, and heat treatments to employ in the process specification.

As a result of numerous tests with different welding rods, welding methods and heat treatments, a suitable welding procedure has been developed for the oxyacetylene welding of carbon-molybdenum alloy steel piping. This procedure when followed by a competent welding operator will produce welds of high strength and ductility and should readily duplicate, if not surpass, the results shown in this paper. The procedure is simple. The principles, modified according to the problems involved, may be applied advantageously to the welding of other low-alloy steels or pressure piping.

WELDING PROCEDURE

A. *Welding Rod* shall be as recommended.

B. *Pipe* shall conform to A. S. T. M. proposed specification A206-38T.

C. *Concurrent Heating*—All pipe of $^5/_8$-inch wall thickness or greater shall be preheated by either of the following two methods listed in the order of their preference:

(*a*) *Continuous Preheat*—The pipe preheat shall be maintained during the entire welding operation by either electrical means or with a single or multi-flame tip applied as close to the weld region as practicable.

I. When using a torch, sections on both sides of the beveled edge at the full thickness of the pipe should be heated to such a temperature as to show red directly under the preheating flames.

II. When using electrical coils, the temperature of the section immediately under the coils should be preferably not less than 1100° F.

(*b*) *Intermittent Preheat*—The pipe preheat shall be applied intermittently by the welding operator at his discretion alternating with the deposition of the weld metal in steps.

D. *Weld Data*

(*a*) *Bevel* pipe to an angle between 30° and 45°, $37^1/_2$° being preferable.

(*b*) *Spacing*—Space pipe ends approximately $^3/_{16}$ to $^1/_4$ in.

(*c*) *Size Rod*—Use $^1/_8$ in. to $^3/_{16}$ in. welding rod for first two layers of multilayer welds.

(*d*) *Multilayer Weld*—Use the multilayer method of welding for wall thicknesses $^3/_8$ in. or greater using at least 1 layer for each $^5/_{32}$ in. of wall thickness.

E. *Heat Treatment*—The entire weld *shall* be normalized after welding by either of the following methods:

(*a*) *Progressive Torch Normalize*—After the welding is completed, reheat the entire weld at least once to temperatures above 1600° F. Start at the end of the last layer of weld metal and reheat the face of the weld until it shows red in a continuous circumferential traverse with the torch.

(*b*) After the hottest portion of the weld has cooled below the critical temperature (or below a red color), reheat the entire weld uniformly to a temperature of at least 1600° F. and allow to cool in still air or at a slower rate of cooling.

F. *Stress Relief*

(*a*) When the progressive method of torch normalizing has been used, the pipe weld shall be heated with the torch or heating coils directly following the torch normalizing pass, to an approximately uniform temperature as indicated by a dull red color.

(*b*) When the weld has been reheated uniformly, an additional stress relief is not necessary if the pipe weld can be slowly and uniformly cooled.

Following this procedure, a practical solution to the problem of economically fusion welding carbon-molybdenum alloy steel pipe will be found in the application of the oxyacetylene welding process—a process in which speed and quality of welding are combined with simplicity of apparatus and economy of operation.

The labor and material savings of the oxyacetylene welds are only indirectly a laboratory problem. The quality of the oxyacetylene welds and the methods of obtaining this quality comprise the main theme of the laboratory's presentation of the subject. The second half of the paper will present the accomplishments of the subject process in actual tests and installations in the field.

SPECIFICATION REQUIREMENTS

In the most recent revised draft in Committee dated February 2, 1940 of the Section on "Welded Pipe Joints" in the American Standards Association's Code for Pressure Piping, Paragraph 9 of Part I on Procedure Qualification of Appendix I requires welded joints in carbon-molybdenum steel pipe to show the physical characteristics tabulated in Table 1.

Table 1—Requirements of A. S. A. Code on Pressure Piping

Reduced Section Tensile Test
Minimum Tensile Strength—Minimum of specified tensile range of plate
Free Bend Test
Minimum Free Bend Elongation, 30%
Restricted Bend Test
Face Bend—No Failure
Root Bend—No Failure

The A. S. M. E. Boiler Construction Code does not cover the welding of carbon-molybdenum steel pipe in the Rules for the Fusion Process of Welding under Section I, referring to the Construction of Power Boilers, principally because the Material Specifications of Section II do not cover carbon-molybdenum steel pipe.

However, under Section VIII referring to the Construction of Unfired Pressure Vessels, 1937, the "Rules for the Fusion Process of Welding" paragraph U-68 may be considered as a pattern for code requirements on this class of work. The weld requirements of unfired pressure vessels are tabulated in Table 2.

In the 1938 Tentative Standards of the A. S. T. M., the tentative specification A206-38T for Seamless Carbon-Molybdenum Alloy-Steel Pipe for service at temperatures from 750 to 1000° F. requires the pipe, before welding, to conform to the requirements of Table 3.

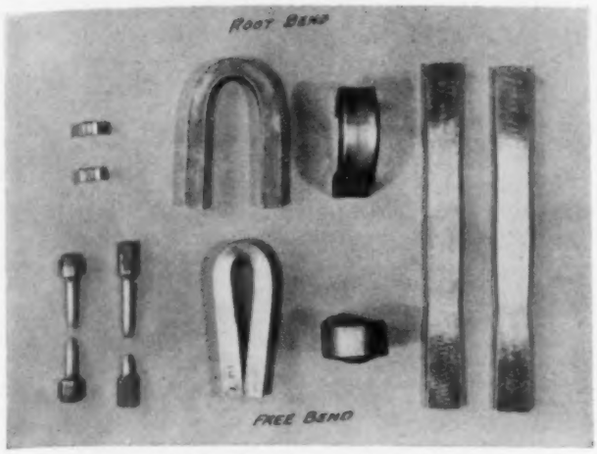


Fig. 1—Typical Carbon-Molybdenum Steel Weld Specimens

Table 2—Requirements of A. S. M. E. Paragraph U-68

* Standard 0.505 Inch Diameter All-Weld-Metal Specimen	
Minimum Tensile Strength—Minimum of	Specified Tensile Range of Plate
Minimum Elongation in 2 inches—20%	
Butt Joint Tensile Specimen	
Minimum Tensile Strength—Minimum of	Specified Tensile Range of Plate.
Minimum Free Bend Elongation—30%	

* All Weld Specimen is omitted for plate less than $^5/_8$ inch thick.

Table 3—A. S. T. M. Tentative Specification A206-38T for Seamless Carbon-Molybdenum Alloy-Steel Pipe, 750° F. to 1000° F.

Chemical Composition	
Carbon, per cent	0.10/0.20
Manganese, per cent	0.30/0.60
Phosphorus, maximum per cent	0.04
Sulphur, maximum per cent	0.05
Silicon, per cent	0.10/0.50
Molybdenum, per cent	0.45/0.65
Physical Characteristics	
Tensile Strength, minimum psi	55,000
Yield Point, minimum psi	30,000
Elongation in 2 inches, minimum per cent	30

The welded pipe specimens are, therefore, required to show a minimum joint and all-weld-metal tensile strength of 55,000 psi, a minimum free bend ductility of 30%, for the all-weld-metal specimen a minimum elongation in 2 inches of 20 per cent, and satisfactory performance of the face and root bend specimens in the restricted bend test.

The data of Table 4 indicate that a minimum tensile strength of 55,000 psi, a minimum free bend ductility of 30% and a minimum weld metal elongation of 20% in 2 inches may be consistently obtained.

The specimens shown in Fig. 1 are typical of the test results. All the specimens with the exception of the standard 0.505 inch diameter tensile test specimens were taken from a 14-inch O.D., 0.75-inch wall, carbon-molybdenum steel pipe weld. The 0.505 inch diameter tensile specimens were machined from the weld metal of similar welds on 0.75-inch plate. The bend and full section tensile specimens indicate the quality of the welds. There is not a sign of a failure in the welds until the free bend specimen flattens out on itself or the full section tensile specimen fails in the base metal.

All preheating, concurrent heating, normalizing, and stress relieving were accomplished with the oxyacetylene flame although it is noted in the procedure where deviations from this practice may be permitted depending upon equipment and power available. The weld metal was deposited in continuous layers and the completed weld normalized with a single, progressive pass of the oxyacetylene torch.

In developing a welding procedure, the investigation consisted largely in the development of a suitable welding rod, the study of the multilayer method of welding, and the testing of appropriate thermal treatments to be used in conjunction with multilayer welding.

WELDING ROD

Initial experiments with welding rods were based on the assumption that a molybdenum content of not less than 0.45% was required in the weld metal to ensure appropriate yield points at elevated temperatures. Thus, the welding rods recommended for this class of work carry sufficient molybdenum to ensure a weld metal analysis showing not less than 0.45%.

To determine the deposition efficiency of the molybdenum in a welding rod, a weld was made on short lengths of A. S. T. M. A-38T molybdenum pipe using a rod of somewhat similar analysis, and a welding flame with a slight feather of acetylene.

Table 4—Physical Characteristics of Carbon-Molybdenum Alloy Steel Welds

				Weld Requirements
Single Vee Butt Joints				
Pipe O. D.	$4^1/_2$ inches	8 inches	14 inches	
Wall thickness	0.437 inch	0.75 inch	0.75 inch	
Tensile strength, psi				
Range	62,400/66,500	62,100/69,200	61,300/62,200	
Average	64,600	64,300	61,800	55,000 minimum
Point of failure	In pipe	In pipe	In pipe	
Free bend ductility, %				
Range	28.3/54.4	32.8/44.5	40.3/53.0	
Average	34.6	36.8	46.8	30 minimum
Standard 0.505 Inch All-Weld-Metal Tensile				
Tensile strength, psi				
Range	62,000 to 67,000			
Average	64,100			55,000 minimum
Elongation in 2 inches, %				
Range	24.0 to 28.0			
Average	25.8			20 minimum

Table 5—Chemical Composition of Welding Materials and Weld Metal

	A. S. T. M. Specification A206-38T	Pipe Analysis	Welding Rod	Weld Metal
Carbon	0.10/0.20	0.136	0.123	0.119
Manganese	0.30/0.60	0.40	0.99	0.50
Phosphorus	0.04 Max.	0.012	0.030	0.029
Sulphur	0.04 Max.	0.011	0.010	0.008
Silicon	0.10/0.50	0.16	0.22	0.01
Nickel		0.04	0.05	0.03
Molybdenum	0.45/0.65	0.52	0.43	0.48
Chromium		None	None	

The molybdenum content of the weld metal is practically the mean of the contents of the welding rod and base metal. It was, therefore, concluded that the loss of molybdenum during the welding operation was negligible. The welding rods were, therefore, designed to give weld metal of approximately the same analysis as the base metal with slight modifications to improve the weldability.

WELDING METHOD

The proper welding method for producing strong, ductile oxyacetylene welds in pressure piping has been adequately described in a paper entitled "Multi-Layer Pipe Welding," presented by the authors before the AMERICAN WELDING SOCIETY in Cleveland, 1936, and published in the October issue of the AMERICAN WELDING SOCIETY Journal. The affect of oxyacetylene multilayer welding on weld quality should be well recognized by now so that it has not been considered necessary to describe the method of welding nor the precautions involved.

Further experience with the oxyacetylene multilayer welding of steel has indicated two possible changes in the welding procedure. First, when further improvement in weld quality is desirable despite slightly lowered welding speeds, the nominal thickness of each layer should be decreased from 1/4 to 5/32 inch. Second, under certain circumstances a continuous preheat or an intermittent preheating operation may be incorporated in the method of welding.

The effect of the latter two types of "concurrent heat" on the welding speed and weld quality will be discussed later. A description of the terms "continuous preheat, intermittent preheat, and concurrent heat" will be found in the following list of definitions of a few of the heat treating terms as used in the subject paper.

DEFINITIONS OF TERMS

PREHEAT—The heat supplied to the joint prior to the deposition of weld metal.

WELDING HEAT—The heat supplied to the joint by the welding flame during the deposition of weld metal.

WELDING PERIOD—The over-all period during which weld metal is being deposited in the fabrication of a joint.

CONCURRENT HEAT—The heat supplied to the joint during the welding period other than the welding heat.

CONTINUOUS PREHEAT—A type of concurrent heat which is maintained continuously during the welding period.

INTERMITTENT PREHEAT—A type of concurrent heat which is alternated with periods during which weld metal is deposited.

POSTHEAT—The heat supplied to the joint after the welding period.

(These definitions are intended to clarify the comparison of the two heating methods run concurrently with the welding operation. In one case, the welding flame is preceded by preheating flames that are maintained a few inches in advance of the welding flames. This continuous preheating allows the welding to proceed continuously except to change rods. In the other case, the welder applies the preheat himself by alternately welding, preheating, and welding and uses the same tip for preheating and welding.)

PROGRESSIVE TORCH NORMALIZING PASS—The term applied to the progressive method of normalizing steel with a welding torch by passing the oxyacetylene flame slowly over the surface of the steel in such a manner that each section traversed by the flame is heated to a temperature above 1600° F. (for carbon-molybdenum steel) and allowed to cool in still air.

HEAT TREATMENT

Although the outer layer of a multilayer weld, using the proper steel welding rod, is strong and generally fairly ductile, the requirements of high temperature, pressure piping service make it desirable to obtain still higher ductilities. This can only be obtained through heat treatment by means of heating coils, furnaces or the oxyacetylene flame. The use of a torch normalizing

Fig. 2—Comparison of "As-Welded" and "Normalized" Weld Metal After Etching

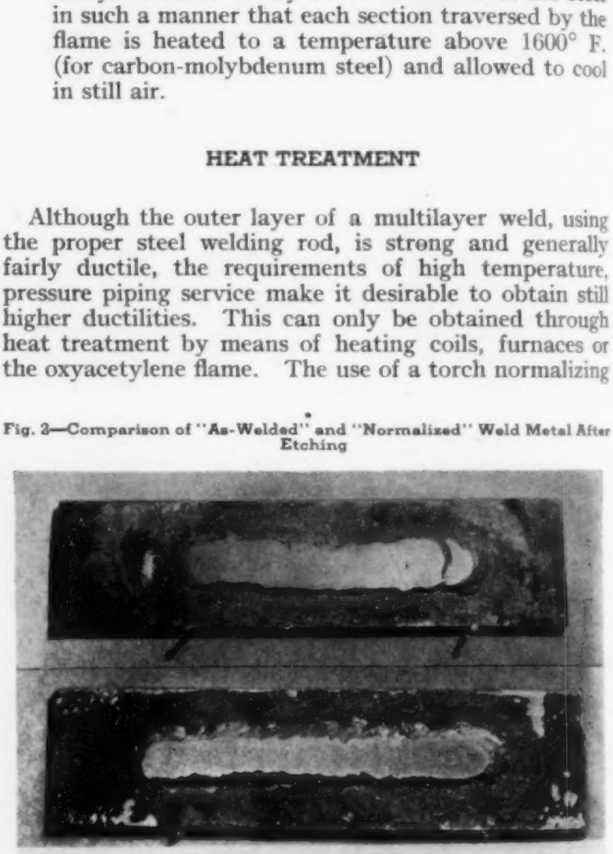


Fig. 3—Comparison of "As-Welded" and "Normalized" Welds After Bending

treatment on the weld metal should be recognized as an economical method of heat treating weld metal to obtain increased ductility.

The normalizing treatment of castings has long been recognized as a suitable method of refining the grain structure and improving the ductility. The same treatment is equally adaptable to refining the grain structure and improving the ductility of the cast weld metal structure. Some welding rods will show fairly good ductilities in the as-welded condition without heat treatment, but oftentimes hard spots are encountered due to the fluctuations in the welding flame. It is the general practice among many qualified operators in welding pressure vessels to use a flame showing a short feather of acetylene. The fluctuations in the gas ratio of the flame during the welding operation may leave sections of carburized weld metal that would show poor ductility in the as-welded condition. The ability of a normalizing treatment to impart ductility to weld metal, that may be carburized, is an important feature of the welding procedure.

To determine whether a progressive torch normalizing pass was applicable to carbon-molybdenum steel weld metal, a simple preliminary test was made. Using a highly carburizing oxyacetylene flame to induce brittleness, a bead of carbon-molybdenum steel weld metal was deposited on each of two $^1/_8$-inch steel strips 1 inch wide and 6 inches long. One of the specimens was then torch normalized by heating to approximately 1600° F. and allowing to cool in still air. Both specimens were then ground, etched in an ammonium persulphate solution, and photographed. The specimens are shown in Fig. 2 and may be easily distinguished by the grain size of the weld metal. The coarser grained specimen is the as-welded specimen.

The specimens were then bent in a guided bend jig. The fine grain specimen that had been torch normalized bent through 180° without a failure. The coarser grain specimen which was in the as-welded condition cracked in two places at a 30° angle.

The photograph of Fig. 3 tells the complete story.

It might be noted here that this test, polishing and etching, is recommended as a ready means of inspection for heat treatment and uniformity of heat treatment.

This illustration is not meant to infer that carbon-molybdenum steel weld metal when not heat treated is brittle—only that such weld metal like most alloy steel weld metals when deposited under a definitely carburizing flame and not heat treated is lacking in ductility. The ductility of carbon-molybdenum steel in the as-welded condition will be intermediate between the ductilities of the two specimens in Fig. 3. The torch normalizing treatment, however, will not only improve the ductility of the weld metal deposited with a neutral flame but will prevent the unwelcome variations due to a fluctuating gas ratio when welding.

WELD DATA

The three sizes of pipe available for the test together with the chemical analyses are given in Table 6.

Table 6—Carbon-Molybdenum Steel Pipe Data

Outside diameter	$4^1/_2$ inches	8 inches	14 inches
Wall thickness	0.437 inch	0.75 inch	0.75 inch
Carbon, per cent	0.134	0.136	0.176
Manganese, per cent	0.47	0.40	0.49
Molybdenum, per cent	0.45	0.52	0.47

The weld data of Table 7 tabulates the sizes and types of carbon-molybdenum steel pipe welds made with carbon-molybdenum steel welding rod. All welds were rolling multilayer welds followed by progressive torch normalizing passes.

Where progressive torch normalizing passes were used, it was only natural to spend an extra minute or two in bringing the pipe weld to a uniform temperature before removing the torch to reduce residual stresses to a minimum. This procedure was adopted as standard practice in making all pipe welds.

MACHINING

Each pipe weld was machined to remove reinforcement, etched to observe the effect of the normalizing treatment, flame cut into strips $1^3/_4$ inches wide, and then machined to full section test specimens approximately $1^1/_2$ inches wide. In certain instances, where the test specimens were to be heat treated, the specimens were not machined after flame cutting.

Pipe weld No. 18 instead of being machined on a lathe and machined after flame cutting was flame cut into strips and the reinforcement ground off.

The ductilities of the flame cut edges of carbon-molybdenum steel pipe were investigated when the first pipe weld was cut into strips. By testing flame cut specimens in bending together with specimens that had been machined after flame cutting, it was found that both methods of finishing gave highly ductile surfaces. Preliminary tests were run with milled surfaces to forestall possible criticism. Later tests were run with flame cut edges since this method of machining is cheaper, more practical, and in time should be more readily acceptable by welding codes.

Table 7—Weld Data

Weld No.	Pipe Diam.	Wall Thickness	Angle Bevel	No. Layers	Preheat (Min.)	Time Welding (Min.)	Torch Normalize
1	$4^1/_2$ inches	0.437 inch	30°	2			
2	$4^1/_2$ inches	0.437 inch	30°	2			
3	$4^1/_2$ inches	0.437 inch	30°	2			
4	$4^1/_2$ inches	0.437 inch	30°	2			
11	$4^1/_2$ inches	0.437 inch	30°	3			
12	$4^1/_2$ inches	0.437 inch	30°	3			
18	$4^1/_2$ inches	0.437 inch	30°	3			
Average					1.4	24.3	3.7
5	8 inches	0.75 inch	30°	3			
6	8 inches	0.75 inch	30°	3			
Average					2.1	81.8	8.4
10	14 inches	0.75 inch	30°	4	2.0	133.0	17.0

Table 8—Specimen Preparation

Weld No.	Thickness, In.	Width, In.	No.	Heat Treatment	Type
1	0.437	1¼	5	Torch normalized	Tensile and Free Bend
			1	* Stress relieved	Free Bend
			2	† Annealed	Tensile and Free Bend
2	0.437	1¼	5	Torch normalized	Tensile and Free Bend
			2	* Stress relieved	Tensile and Free Bend
			1	† Annealed	Free Bend
3	0.437	1¼	5	Torch normalized	Tensile and Free Bend
			1	* Stress relieved	Free Bend
			2	† Annealed	Tensile and Free Bend
4	0.437	1¼	5	Torch normalized	Tensile and Free Bend
			2	* Stress relieved	Tensile and Free Bend
			1	† Annealed	Free Bend
11	0.437	1¼	8	Torch normalized	Tensile and Face Bend
12	0.437	1¼	8	Torch normalized	Tensile and Face Bend
18	0.437	1¼	12	Torch normalized	Tensile, Face and Root Bend
5	0.75	1¼	8	Torch normalized	Tensile and Free Bend
			3	* Stress relieved	Tensile and Free Bend
			3	† Annealed	Tensile and Free Bend
6	0.75	1¼	8	Torch normalized	Tensile and Free Bend
			3	* Stress relieved	Tensile and Free Bend
			3	† Annealed	Tensile and Free Bend
10	0.75	1¼	21	Torch normalized	Tensile, Free, Face and Root Bend

* Stress relief—¾ hour at 1225° F.
† Anneal—1 hour at 1750° F.—Furnace cool to 1250° F.—Aircool.

RESULTS OF TEST

The first six pipe welds on 4½-inch O.D., 0.437-inch wall, and 8-inch O.D., 0.75-inch wall carbon-molybdenum steel pipe were tested in tension and in bending in the torch normalized, stress relieved and annealed conditions.

The specimens of Fig. 4 representing the first four pipe welds show readily enough that the weld metal was ductile and, when free from welding defects, stronger than the base metal. Even the tensile specimens that failed in the weld metal showed tensile strengths from 59,600 to 66,100 averaging 63,400 which is well above the allowable minimum of 55,000 psi. The presence of these minor flaws were eliminated by practice and refinements of welding procedure in later welds on this size pipe, so that all tensile specimens failed in the base metal.

The specimens of Fig. 5, representing the ¾-in. wall pipe welds, speak for themselves. The free bend specimens were flattened on themselves without failure while the tensile specimens all failed in the base metal. The specimens of Figure 6 show the relatively small variations in ductility between the various heat treatments. Of course, the welds in the "stress relieved" condition have been "torch normalized" prior to stress relieving. The effectiveness of the torch normalizing treatment in treatment in cooperation with the multilayer welding technique in providing ductile weld metal is particularly evident.

The results of the tests on the first six pipe welds are tabulated in Table 9.

The six welds as noted in Table 9 were made in continuous layers followed by a progressive torch normalizing pass. In the torch normalized condition the tensile strength (64,000 psi average) and free bend ductility (35.2% average) were quite satisfactory, indicating that further heat treatment was unnecessary.

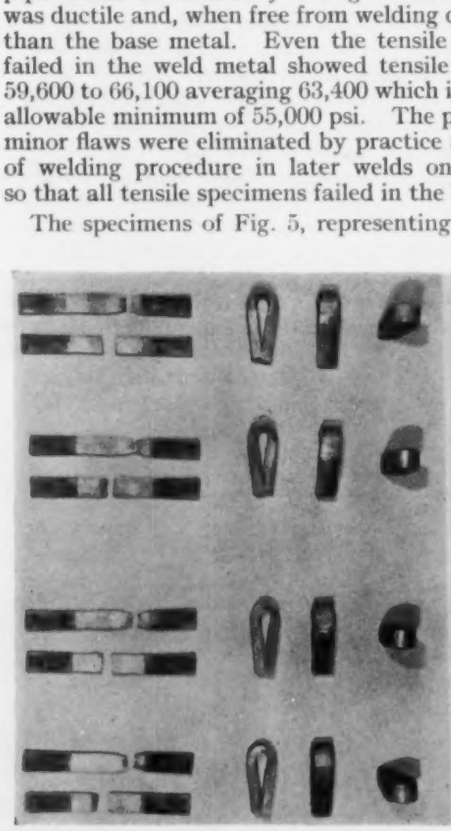


Fig. 4—Tensile and Free Bend Specimens from Pipe Welds 1, 2, 3 and 4

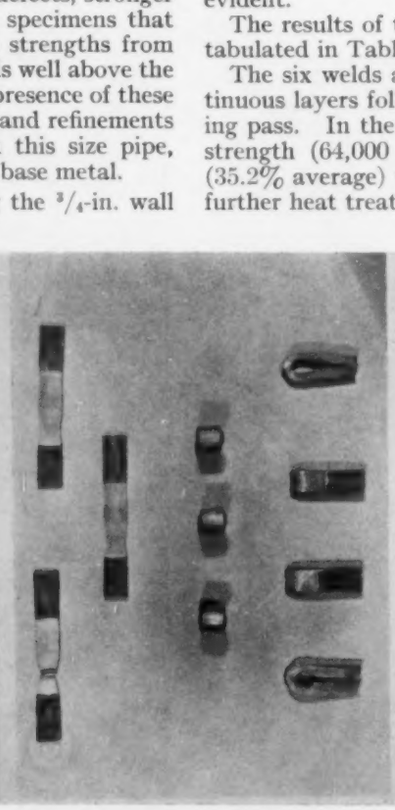


Fig. 5—Tensile and Free Bend Specimens from Pipe Welds 5 and 6

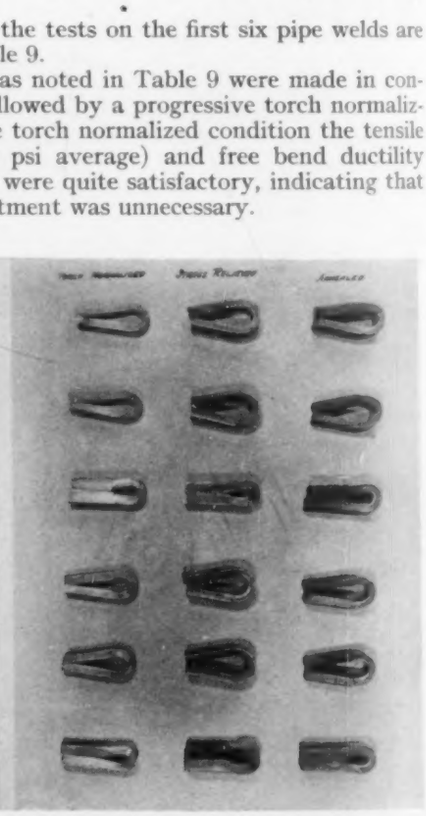


Fig. 6—Comparison of Free Bend Ductilities of Torch Normalized, Stress Relieved, and Annealed Specimens of Pipe Welds 1, 2, 3, 4, 5 and 6

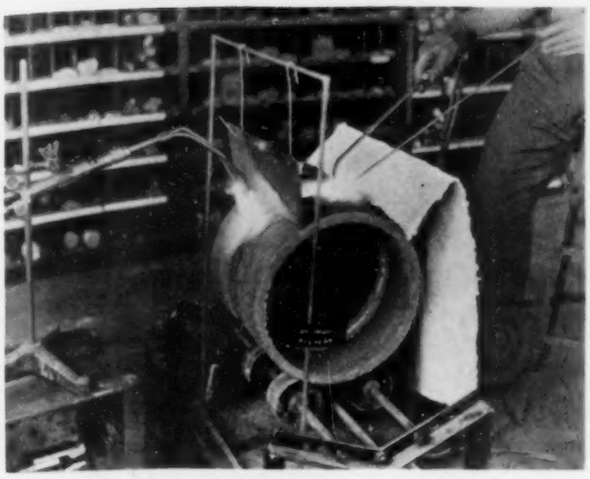


Fig. 7—Welding Pipe Using Continuous Preheat

Table 9—Effect of Thermal Treatment on Carbon-Molybdenum Steel Pipe Welds (1–6)

Outside Diameter	4½ inches		8 inches
Wall Thickness	0.437 inch		0.75 inch
	Torch Normalized	Stress Relieved*	Annealed†
Tensile strength in psi			
Range	59,600 to 69,200	57,400 to 58,900	51,900 to 53,000
Average	64,000	58,200	52,400
Free bend elongation in %			
Range	28.3 to 54.4	25.7 to 44.2	31.2 to 47.2
Average	35.4	35.4	36.8
Rockwell "B" hardness			
Range	72 to 80	72 to 80	63 to 79
Average	75	74	70
Equivalent Brinell (3000-10-30)	159	147	125

* Stress-Relief—¾ hour at 1225° F.

† Anneal—1 hour at 1750° F., furnace cool to 1250° F. and air cool.

The stress-relieving treatment has lowered the tensile strength of the plate from 64,000 to 58,000 psi, but has had little apparent effect upon the weld metal ductility as measured by the free bend test or upon the Rockwell hardness. It should be remembered, of course, that the stress relieved and annealed specimens have undergone a normalizing pass with the oxyacetylene torch and so are fairly ductile to begin with.

The tensile strengths of the annealed specimens were below the desired minimum of 55,000 psi, so that a high anneal (1750° F.) on this class of work should be avoided if the present code requirements are to be satisfied.

The welds, incidentally, also indicated that the temperature gradients set up during the welding operation were sufficiently gradual to prevent objectionable residual stresses and eliminate shrinkage cracks.

The first six welds were thus sufficient to substantiate our choice of welding procedure and to indicate that a multilayer carbon-molybdenum steel pipe weld after torch normalizing does not require appreciable further heat treatment.

The physical characteristics of the welded joint in welds No. 5 and 6 on 8-inch, ¾-inch wall pipe conformed to the test requirements of 30% minimum free bend ductility and 55,000 psi minimum tensile strength. The surface appearance of the bend specimens, however, revealed occasional minute flaws that appeared to be characteristic of the welding procedure.

To reduce these occasional flaws and to secure a more complete set of test specimens from a single pipe weld, a weld was made on a ¾-inch wall pipe of 14-inch O.D. using a continuous preheat, while welding.

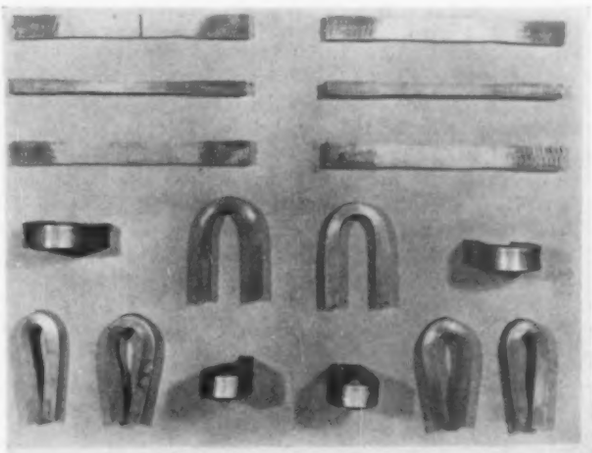
The pipe walls of pipe weld No. 10 were preheated by a two flame oxyacetylene torch about 8 inches ahead of the welding torch so that the welding operator could use a lower gas flow and maintain a less turbulent puddle of weld metal. Since the weld was a rolling weld, the preheating torch was held in position by a portable vise and the pipe rotated by a motor-controlled unit operated by foot pedal by the welding operator or his helper.

The quality of the weld is illustrated by the specimens of Fig. 8 which were tested in tension, restricted face and root bend, and the face bends then flattened until the ends touched. All tensile specimens failed outside the weld in the pipe at stresses between 61,300 and 62,200 psi. The face and root bends took the full bend without a sign of a flaw. The flattened face bends showed from 40 to 53% elongation across the face of the weld, without showing a flaw.

Charpy impact specimens taken from the face and root of the weld, with similarly located specimens taken from the pipe, were tested and the results tabulated in Table 10.

The advantage of the continuous preheating of the pipe walls during the welding is most evident to the welding operator, who is relieved somewhat from the strain

Fig. 8—Tensile, Root Bend and Flattened Face Bend Specimens of Pipe Weld 10



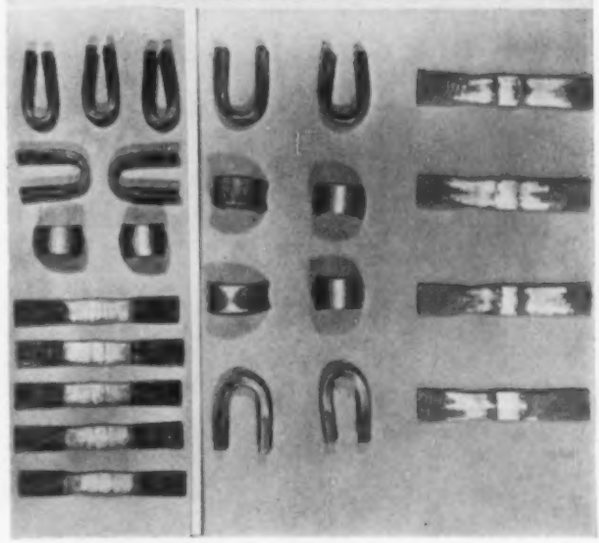


Fig. 9—Tensile and Bend Specimens from Pipe Welds 11 and 12

Fig. 10—Tensile, Face and Root Bend Specimens from Pipe Weld 18

Table 10—Impact Strength (Charpy Keyhole Notch) of Carbon-Molybdenum Steel Pipe Welds

Position of Specimens	Weld	Pipe
Root	32.0	39.0
	35.5	35.5
Face	33.5	41.0
	29.0	41.0

of controlling a molten puddle of weld metal with a harsh gas flow. The net result is more uniformly high quality and a more consistent freedom from flaws unless the operator is unusually experienced in the welding of heavy wall pipe. In case the welding operator dispenses with the continuous preheating, it is desirable that the welding proceed intermittently by alternating small weld steps with equivalent periods of preheating. The speed of welding is naturally reduced, but by means of frequent preheating the welding operator regains much of his ability to weld with the lower gas flows necessary for the deposition of sound, ductile weld metal. The continuous preheating seems to have no effect on the weld quality other than the indirect effect through the simplification of the welding operation. It does, however, definitely improve the speed of welding.

To find the effect of variations in the melting practice with different size heats, a 2000 lb. heat 1 x 926 was obtained. The previous heats were experimental 30-lb. heats.

To check the performance of the welding rod heat 1 x 926, pipe welds No. 11 and 12 were made on $4^1/_2$-inch O.D. pipe by the laboratory operators, using the same welding and normalizing procedure that was used in making the first four welds. To simplify the machining and to revert to a method of machining that had been developed coincident with the multilayer method of welding and checked early in this investigation on C-Mo pipe, the reinforcement was machined from the face of the weld in a lathe and the pipe then flame cut into test specimens and tested without further machining.

The weld specimens were tested for tensile strength and soundness by means of tension and guided bend tests. To determine the ductility the guided bend specimens, which had previously been gage marked, were flattened in a vise until the elongation showed at least 30%.

The specimens of Fig. 9 were similar to the ones of pipe welds 1, 2, 3 and 4. All tensile specimens failed in the pipe at stresses between 62,800 and 65,600 psi; the face bend specimens did not show a single flaw, while the free bend test specimens showed over 30% ductility.

A third pipe weld No. 18 was made with the carbon-molybdenum heat 1 x 926 on the $4^1/_2$-inch pipe to check a third method of machining. This method approximates a field method of testing in which a cutting torch and grinding wheel are the only tools available with which to machine the test specimens.

Possibly such rough methods of machining will never be used on carbon-molybdenum steel pipe. Nevertheless, the test specimens, flame cut to width and with the reinforcement roughly ground off, readily show when tested that the weld metal is stronger than the pipe and that the face and root bend specimens take a 180° bend without failure.

ALL-WELD-METAL TENSILE TESTS

To determine the physical characteristics of standard 0.505-inch all-weld-metal test specimens, single vee butt joints were welded in $^3/_4$-inch plate, 10 inches long, and beveled at a 30° angle. The welds were made in five layers using the latest carbon-molybdenum steel welding rod from heat 1 x 926 and depositing each layer of weld metal in two inch increments alternating with periods of preheating. Half the specimens were progressively torch normalized after the welding operation.

The photograph of Fig. 11 shows the size and shape of each layer obtained by welding a 10-inch specimen in steps and cutting a section from the foot of each step.

Table 11—Effect of Torch Normalizing on Physical Characteristics of 0.505 Inch Diameter, All-Weld-Metal Specimens

	As-Welded	Torch Normalized
Tensile strength, psi		
Range	71,000 to 86,200	62,000/72,300
Average	76,600	66,100
Yield point, psi		
Range	49,000 to 60,000	34,000/39,000
Average	52,600	37,000
Elongation in 2 inches, %		
Range	10.0/23.0	24.0/28.0
Average	15.4	25.8
No. of specimens tested	12	6

The results of the all-weld-metal tensile tests are tabulated in Table 11. They indicate primarily that torch normalizing the welded joint has increased the average elongation by 10% while lowering the tensile strength to not less than 62,000 psi. They also indicate a greater variation in the "as-welded" test results than in the "torch-normalized" results.

The as-welded specimens when polished and etched showed a varying grain structure ranging from the fine

Fig. 11—Step-by-Step Section of Multilayer Weld

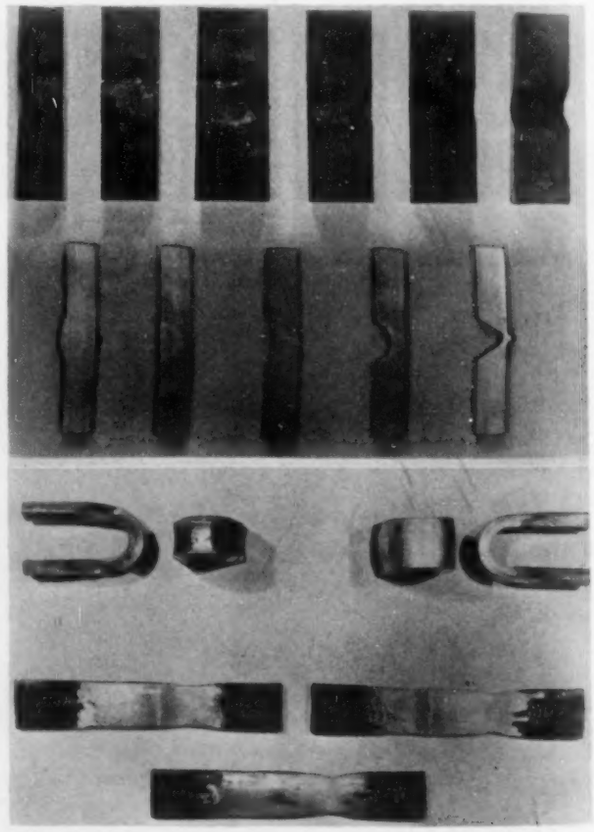


Fig. 12—Tensile, Face and Root Bend Specimens from Pipe Weld 19

grain lower layers to the coarser grain final layer. The variation in ductility in the 0.505 inch diameter all-weld-metal tensile test is due to these differences in weld metal structure. When the cross section of the test specimen lies entirely in the lower layers, the maximum ductility is obtained. When some of the coarser structure of the upper two layers are included, the ductility drops down to 10%. Torch normalizing, by refining the grain structure of the outer layers particularly, makes the weld structure more uniform and increases the ductility beyond the best results obtained with the as-welded specimens.

All physical test results shown up to this point were obtained with welding rods designed to give weld metal of approximately the same analysis as the base metal with slight modifications to control the weldability.

To improve the weld metal ductility, an additional experimental heat of welding rod with lower carbon and manganese, heat 3755, was made up and tested, and the test results tabulated in Table 12.

Table 12—Chemical Composition vs. Physical Characteristics

	Heat 1 x 926	Heat 3755
Carbon	0.09	0.02/0.03
Manganese	1.03	0.48
Phosphorus	0.017	0.004
Sulphur	0.028	0.019
Silicon	0.22	0.20
Nickel	0.57	0.43
Chromium	0.06	0.12
Molybdenum	0.56	0.46
Results of 0.505-Inch All-Weld-Metal Tensile Tests		
Tensile strength, psi		
Range	62,000 to 72,300	60,300 to 63,000
Average	66,100	61,300
Elongation in 2 inches, %		
Range	24.0 to 28.0	22.0 to 33.0
Average	25.8	27 9

The lowering of the carbon and manganese has dropped the average tensile strength from 66,100 to 61,300 psi while increasing the ductility from 25.8 to 27.9%.

A $4^1/_2$-inch O. D., 0.437-inch wall pipe weld was made with the heat No. 3755, machined to full section tensile and bend specimens and tested.

All the tensile specimens of Fig. 12 failed in the base metal. The face and root bend specimens took a full bend in the guided bend jig without the sign of a flaw.

A typical free bend specimen shown in Fig. 13 shows an elongation of over 30%.

A 0.505 inch diameter all-weld-metal specimen made with this heat is shown in Fig. 14.

The numerous bend and tensile tests of the welded joints and weld metal were sufficient to indicate that cracks were not formed during the oxyacetylene welding of the carbon-molybdenum steel base metal. The investigation of the stresses remaining in the pipe weld after the welding operation was completed was, therefore, not pursued very intensively. The determination of the longitudinal residual stresses existing in welded pipe depends upon the piping design and the fixity of the joint as it is welded in the field. Consequently, the circumferential stresses alone were studied.

By measuring the increase in pipe diameter or the separation of the pipe walls after slitting the butt joint longitudinally, the amount of constrained circumferential shrinkage was determined. Pipe welds No. 11 and 12 showed an increase in diameter of 0.0045 inch and 0.0084 inch, respectively, in $4^1/_2$ inches.

Using the method of computing the residual stresses in welded pipe described by E. L. Eriksen and I. A. Wojtaszak, in the AMERICAN WELDING SOCIETY JOURNAL for October 1938, the circumferential stresses were computed to be of the order of 3600 and 5700 psi, respectively. These values compare favorably with those obtained by Eriksen and Wojtaszak on electric welded $8^5/_8$-inch O. D., $^1/_2$-inch wall pipe stress relieved at 1200° F. (3000/4000 psi).

DISCUSSION OF RESULTS

The principles involved in the thermal treatment of carbon-molybdenum alloy steel welds are no different from those applicable to the majority of low-alloy steel weldable materials.

The methods of heat treatment can be divided into three classes: Preheating, Concurrent Heating and Postheating. The tests of the carbon-molybdenum steel welds have indicated the heat treatments that are the most desirable from the laboratory point of view.

Although in some instances they may not be deemed practical, the fundamentals of heat treatment are sound. The thermal treatments, of course, may be modified or omitted at the discretion of the engineer-in-charge or the designer when backed by process and operator qualification tests.

Preheating.—In the oxyacetylene welding of A. S. T. M. A206-38T carbon-molybdenum alloy steel pipe, it is thus demonstrable that separate preheating as a means of preventing cracking of the weld or base metal is entirely unnecessary. The nature of the oxyacetylene flame creates more gradual temperature gradients, lower thermal stresses, and permits the application of the welding flame to the steel surface with little danger of cracking.

On the other hand, the use of separate preheating in the application of oxyacetylene welding to carbon-molybdenum steel possesses distinct advantages that make it advisable to continuously preheat the base metal ahead of the welding flame for the highest quality of work on the heavier wall thicknesses.

Concurrent Heating.—The deposition of weld metal with

Fig. 13—Typical Free Bend Specimen

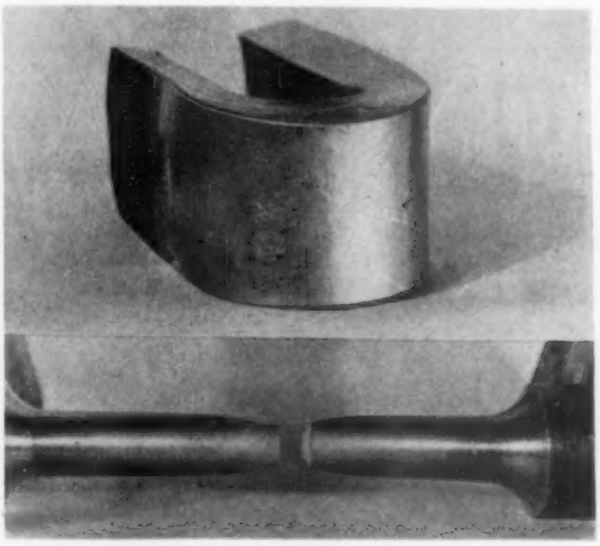


Fig. 14—Standard 0.505 Inch Diameter All-Weld-Metal Specimen

high ductility is governed by the time, temperature and working conditions when molten. The less that weld metal is overheated and the quieter it is deposited, the greater will be the ductility. With a single torch, the same tip does both the welding and preheating of the pipe. As the welding heat is cut down to secure more sound weld metal, the pipe preheat suffers and the tendency is to secure a weak bond.

The proper balance between welding and preheating may be obtained with single tips for standard weight pipe. As the wall thickness increases, however, the pipe needs more preheat. If sufficient heat is used in a single flame to provide for continuous welding, the weld metal is usually overheated and of mediocre ductility. To allow the weld metal to be deposited quietly without overheating by the use of a smaller welding flame, the pipe must be preheated either continuously during the welding from a source other than the welding flame, or the welding flame must be applied intermittently to the pipe walls as a preheating flame during the course of the welding operation. This preheating to distinguish it from any heating of the base metal prior to the application of the welding flame, is termed "concurrent heating."

It is not meant to infer that concurrent heating in the oxyacetylene welding of wall thicknesses over $^1/_2$ inch is necessary as with the requisite experience, a good operator can still secure strong ductile weld metal free from troublesome porosity or inclusions without any concurrent heating. Wherever possible, however, a heating torch with a single or multi-flame tip should be set up to maintain a separate preheat directly in advance of the welding flame, whether operated manually or semi-automatically. This concurrent heating improves the speed of welding at the same time as it improves the quality.

Postheating.—Since early in 1935 it has become increasingly evident that alloy steel weld metal, when deposited with the oxyacetylene flame, should have the original cast structure refined by a heat treatment operation following the completion of the weld. The grain-refining effect of the multilayer deposition of weld metal is not quite satisfactory for optimum results as the upper layer of weld metal is not so fine grained as the remainder of the weld.

The ideal treatment appears to be a 1500° F. furnace anneal, but as this is oftentimes impracticable due to lack of available and economically operable equipment and as it is often unsatisfactory due to a reduction in ultimate tensile strength, it is recommended in view of the results of weld tests that the weld after completion be normalized by being heated above the critical and allowed to cool slowly in still air.

This normalizing treatment may be accomplished in two ways. First, it may result from a progressive pass of the welding torch around the pipe. Thus, after the welding is completed, the entire weld is reheated to temperatures above 1600° F. by heating the face of the weld to at least 1750° F. in a continuous circumferential traverse with the torch starting at the end of the last layer of weld metal.

Second, the weld may be allowed to cool until the entire weld has cooled below the critical temperature (or below a red) after which it is reheated uniformly to 1600° F. and then allowed to cool slowly in still air.

The difference between the two methods lies in the uniformity with which the welds are normalized. A progressive normalizing pass with the welding torch oftentimes does not give as uniform ductility as a weld that has been allowed to cool entirely below a red and then reheated all together to a normalizing temperature. The former method is faster but requires more experience and an occasional etch test for grain size as a check.

Finally, stress relieving at the completion of the weld is still used although somewhat modified. If a progressive torch normalizing operation has been used, then the pipe is reheated uniformly to not less than 1100° F. before being allowed to cool. If a uniform normalizing heat has been applied, the normalizing treatment can be considered a stress relief.

Therefore, in order to obtain oxyacetylene welds in carbon-molybdenum steel pipe that will conform to the A. S. A., the A. S. M. E., or other code requirements, it is necessary to use a suitable welding rod, the multilayer method of welding, and a normalizing treatment after welding. This oxyacetylene welding procedure is equally applicable to the welding of the majority of low-alloy steels or the welding of structural steels with the majority of low-alloy steel welding rods.

OXYACETYLENE WELDING OF Carbon-Molybdenum Steel Pipe

Part II—Field Testing and Application*

By A. N. KUGLER†

CARBON-MOLYBDENUM steel piping is employed under practically the severest operating conditions now existent for power piping. It should therefore be obvious that the welding of this steel requires the highest quality. Virtually all of this type of piping installed to date has been arc welded with carbon-molybdenum electrodes. The only exception to this has been on superheater tubes. The quality of this welding has been entirely satisfactory; the speed of welding has been extremely low and consequently costs have been high. This has prompted many users to inquire as to the possibility of employing the oxyacetylene process. Contrary to the common conception oxyacetylene pipe welding is no slower and no more costly than equivalent competitive processes. Data

* Paper presented at the 40th Annual Convention of the International Acetylene Association, April 10th, 11th and 12th, Milwaukee, Wisconsin.

† Mechanical Engineer, Applied Engineering Department, Air Reduction Sales Company, New York, N. Y.

collected by a large eastern utility company on the welding of heavy wall plain carbon steel pipe indicates that oxyacetylene welding is performed in one-third to one-half the time required by other standard procedures. The greater difference in production occurs in general in the small sizes and lighter weights, while lesser differences occur in the larger diameters and greater wall thicknesses. The range covered by this study is from 4 by 0.531-inch wall to 18 by 1.75-inch wall.

It was with full realization of the requirements of this field and the inherent advantages of the oxyacetylene process that we undertook the field testing of carbon-molybdenum gas welding rods and the attendant welding procedure. In general the function of field tests is to apply the laboratory's findings on actual construction or under field conditions to determine, first, whether the laboratory results can be duplicated and, second, whether any changes or modifications are necessary to render the operation practicable and economical for industry. This field work has involved tests or actual applications at some twenty different points representing piping fabricators, power companies, industrial power plants, boiler fabricators and other allied industries. While results from all of these tests are not available at the moment sufficient data are on hand to permit us to state that our work confirms the findings of the Research Laboratory. Only minor modifications have been necessary to adjust the procedure to field conditions.

In these field tests we have welded carbon-molybdenum steel pipe ranging from 3 by 0.4375-inch wall up to 14 by 0.875-inch wall. These welds have been submitted to practically all of the standard tests including those required under the American Standards Association Code for Pressure Piping. It should be realized that where the laboratory welds are entirely made in the rolling position the field tests are made in all positions, viz., fixed horizontal position, fixed vertical position and roll welds. These field results may, therefore, be taken as representative of what may be expected in actual construction.

Since current code requirements indicate the stress relieving of carbon-molybdenum steel welds, all of the following results are taken on specimens which have had the benefit of this treatment. Practically all of the specimens have been stress relieved by means of the oxyacetylene torch, heating the joint to 1400–1500° F. and immediately wrapping and otherwise providing for slow cooling. A more detailed discussion of stress relieving will be undertaken later. It is interesting to note that included in the field test results are the figures for two welds made by shop operators under the identical conditions required for qualification test welds.

The welding procedure employed in all this field work is substantially that outlined in Part I. The open single-vee butt joint without backing up strip or liner has been used almost exclusively. The bevel preparation comprehended 30–37$^1/_2$ degree bevel angles with or without the usual land depending on whether the joints were prepared by machine tool beveling or machine torch cutting. The multilayer welding technique has been employed exclusively with but the one slight modification of thinner layers. On rolling welds it has been found entirely acceptable to employ layers as thick as $^3/_{16}$ inch. On position welds it has been found desirable under some adverse conditions to resort to layers as thin as $^5/_{32}$ inch. Continuous deposition of layers is preferable in this welding.

The following rod sizes have been found to be desirable for the various thicknesses welded under the given conditions: for rolling welds the first layer should be made with the $^1/_8$ inch diameter rod and the intermediate layers up to $^3/_4$ inch thickness with $^3/_{16}$-inch rods; intermediate layers above $^3/_4$ inch thickness should be made with $^1/_4$-inch rods and the final layer is best made with the $^1/_4$-inch rod. On position welds the first layer should be made with $^1/_8$-inch rods and the intermediate and final layers with $^3/_{16}$-inch rods.

One further factor merits attention in the oxyacetylene welding procedure. Separate preheating of carbon-molybdenum steel for oxyacetylene welding is not necessary. The inherent preheat available in the oxyacetylene flame has been found to be entirely adequate for the majority of joints to date. In the heavier wall thicknesses it sometimes proves advantageous on the first few layers to alternately preheat and weld with the torch. Separate preheating may be desirable under some circumstances especially in shop fabrication to expedite the work. It should be remembered, however, that a separate source of preheat is not essential and, therefore, should not be required by a process specification.

The results of the physical tests conducted on these field welds are only of value in so far as they confirm the laboratory work and prove that field welding meets current requirements. Since endless tabulations of tensile, bend and other tests are of little value at this point the results of all of these tests have been summarized and given as a range together with the average values in Table 1. It will be readily seen that the reduced section tensile test figures indicate full compliance with code requirements. The welds develop an ultimate tensile strength equal to or exceeding that of the base metal which is all that is necessary. Since the longitudinal all-weld-metal tensile test specimen is not generally employed in the field for process or operator qualification little attempt has been made to include this in the field tests.

Table 1—Physical Properties

Reduced Section Tensile Test	
Ultimate Tensile Strength	63,000 psi avg. (61,000–65,750)
Yield Point	42,000 psi avg. (40,800–44,970)
All Failures Outside Weld	
Free Bend Test	
Average Elongation—46% avg. (40–51)	
Nick Break Test	
Silky Fractures—Fine to Very Fine Grain—Slight Porosity Occasionally	
Back Bend Test	
Bent 180°—Only One Specimen Bent Less (140°)	
Side Bend Test	
Test Made on $^3/_8$ Inch Thick Specimens in Restricted Bend Test Jig—Bent 180°	
Restricted (Guided) Bend Test	
All Specimens Tested Readily Bent 180° on Both Face and Root Bends	

The next logical tests made in the field investigation were the various bend tests, including free bend, restricted bend (both face and root) and side bend. It should be appreciated that these tests are really qualitative and more indicative of operators' ability rather than determining specific physical constants. Table 1 shows that the free bend elongation ranges from 40–50 per cent which is entirely adequate and well above the minimum. The guided bend test which is more severe than the old free bend test shows further that these welds are possessed of a high degree of ductility. The side bend

test, made in the restricted bend test jig, further emphasizes this fact.

The nick break test has been included in this work for the reason that it is still part of the requirements of the American Standards Association Code for Pressure Piping, edition of 1935, which edition is still in force although shortly to be superseded by a later one. The nick break test has perhaps come into disrepute recently due to the inability of some inspectors to interpret the fractures. This fact should not permit us to entirely disregard this test because it still possesses the merits of simplicity and ready application. The nick break test still provides an intelligent inspector with a wealth of information. It is interesting to note that on all of the specimens examined in the field a very fine grain structure was evident with a minimum of defects. Uniformly good fusion throughout the weld cross section is found.

Other additional tests have been included in this field investigation for the purpose of developing further the average properties of these welds. Among these have been chemical analysis of deposited metal. Since the analysis of the welding rod has been covered under Part I we have covered only typical results in the weld metal in Table 2. It should be realized that the analysis of the pipe metal will have a marked influence upon the deposited metal analyses. Any variations which exist are doubtless due to this fact since the welds were on pipe from many sources.

Table 2—Chemical Analysis

Test	C	Mn	P	S	Si	Mo
A	0.09	..*	...*	...*	..*	0.65
B	0.10	0.60	0.021	0.010	0.03	0.68

* Not taken on this test.

The weld metal density was checked at one point of test and found to be 7.83. This exceeds the minimum value prescribed and is therefore entirely acceptable.

Charpy impact tests conducted at room temperatures produced satisfactory results as indicated in Table 3 and Fig. 1.

FIG 1
LOCATIONS OF IMPACT SPECIMENS

LOCATION OF BARS & IMPACT VALUES FT. LBS.-CHARPY 85°F							
FUSION ZONE 1	WELD LOWER 2	WELD CENTER 3	WELD UPPER 4	FUSION ZONE 5	ADJACENT METAL 6	ADJACENT METAL 7	ADJACENT METAL 8
41	48	35	35	45	48	49	47

TABLE III
IMPACT VALUES

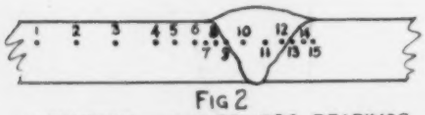


FIG 2
LOCATIONS OF HARDNESS READINGS

LOCATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
BRINELL HARDNESS NO.	134	132	142	133	130	130	139	135	142	156	186	131	137	129	119

TABLE IV
HARDNESS

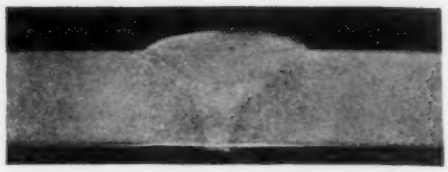


Fig 3—Macrograph of Weld on 0.718 Inch Wall Pipe

A hardness exploration conducted on the base metal, heat-effected zones and deposited metal indicate that the maximum is well below 200 Bhn. The actual figures are shown in Table 4 while the various points are illustrated in Fig. 2. In Fig. 3 is shown a photograph of weld cross section magnified approximately two times. The variations in grain structure in the different zones is clearly defined. One slight foreign inclusion is evident in the first layer. This illustration shows clearly the benefits derived in grain refinement by multilayer welding.

In Fig. 4 are shown four photomicrographs (100×) illustrating at (*a*), the unaffected parent metal; at (*b*), the heat-effected zone; at (*c*), the junction between the first layer of weld metal and the base metal; and at (*d*), the junction between the second and third layers of weld metal. Again the grain refinement due to multilayer welding is adequately demonstrated.

In addition to these field tests, one small installation has been completed in the middle-west. This system operates at 1800 psi and 900° F. and involves the following sizes of pipe: 2 by 0.438 inch, 3 by 0.563 inch and 4 by 0.674 inch. This piping has been installed for service to a group of heaters. Multilayer welding employing three layers of weld metal was used on all three sizes of pipe. The work was performed under the usual field difficulties and involved all of the usual types of joints. Stress relieving was accomplished with oxyacetylene torches heating the joints uniformly to a temperature of 1400–1450° F. and immediately upon reaching that temperature covered the joints with asbestos blankets or paper and plugging any open ends. The stress-relieving temperature was checked with a pyrometer. This project was installed by the owner's forces and no attempt was made to rush the job. The following interesting production data were obtained during the course of construction:

- 3-inch position weld 50 minutes plus 5 minutes for stress relief
- 3-inch rolling weld 40 minutes plus 5 minutes for stress relief
- 2-inch position weld 40 minutes plus 4 minutes for stress relief
- 2-inch rolling weld 30 minutes plus 3 minutes for stress relief

The daily production rate averaged eight 3-inch or ten 2-inch welds. Under test conditions and in approximately one year's operation no leaks or failures of any nature have developed. One of the expansion loops is illustrated in Fig. 5.

Additional data, although admittedly incomplete has been reported from several points. An eight inch 0.625-inch wall CMo pipe was welded in $1^1/_2$ hours (roll weld) and stress-relieved at 1400–1450° F. in 17 minutes with two torches. This joint required 80 cu. ft. of oxygen, 70 cu. ft. of acetylene and 2.75 lb. rod. Post heating consumed 45 cu. ft. oxygen and 38 cu. ft. acetylene. Other reported data include $2^1/_4$ hours for welding $10^5/_8$ by 0.718-inch wall pipe and 3 hours for 14 by 0.75-inch wall pipe. It should be appreciated that this information is insufficient basis for estimating purposes.

(a) Unaffected parent metal (b) Heat affected adjacent metal (c) Junction between first layer of weld and parent metal (d) Junction between 2nd and 3rd layers of weld metal

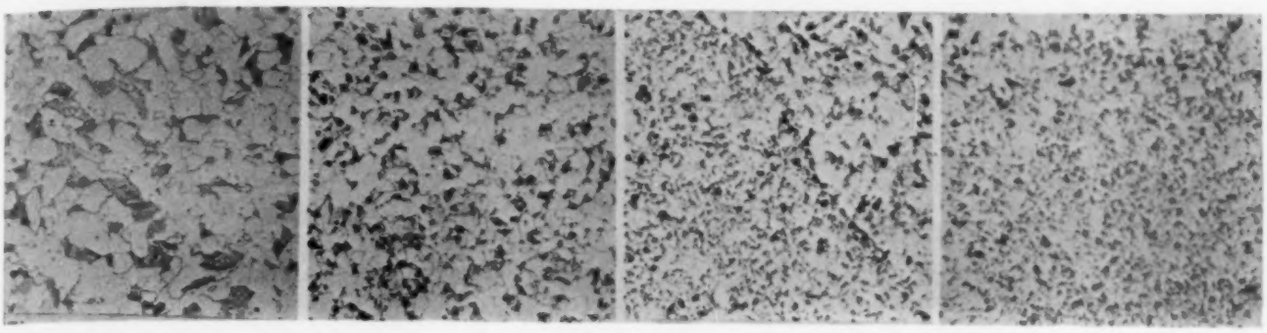


Fig. 4—Microphotographs 100X

One further practical application is in the process of development at the present moment. A large fabricator of superheaters is training their shop force for the welding of superheater tubes with this welding rod. It is planned to use this process and rod on the fabrication of a very large superheater unit to be built shortly.

Based upon these field tests and applications we have prepared a "Process Specification for Oxyacetylene Fusion Welding of Carbon Molybdenum Steel Pressure Pipe Lines," which is given herewith.

PROCESS SPECIFICATION FOR OXYACETYLENE FUSION WELDING OF CARBON-MOLYBDENUM STEEL PRESSURE PIPE LINES

Base Material

The base metal shall conform to American Society for Testing Materials specification serial designation A206-38T.

Process

The welding shall be performed by the oxyacetylene process.

Filler Metal

The filler metal shall be carbon-molybdenum oxyacetylene welding rod.

Welding Groove

The welding groove shall conform to details as shown in Drawing No. 1.

The same welding groove shall be used for vertical and horizontal pipe welds.

When it becomes necessary to bevel pipe in the field, machine guided oxyacetylene torches shall be used. It shall not be necessary to provide a land or shoulder on these joints.

Cleaning of Welding Groove

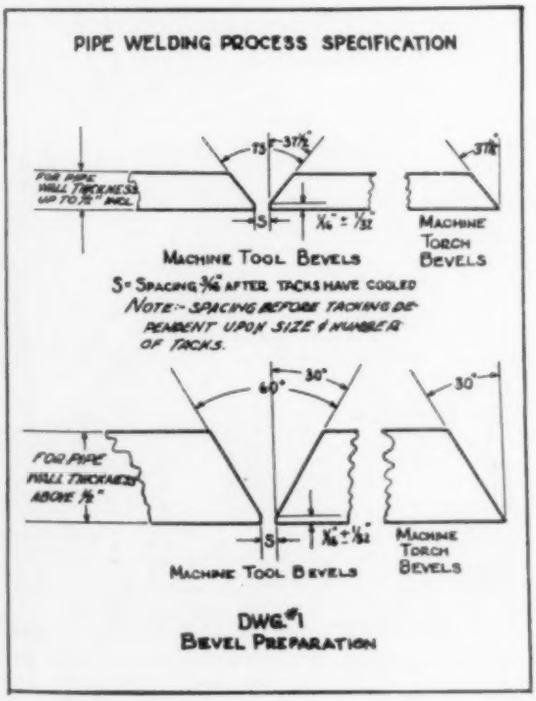
Prior to welding, the edges of the pipes and the surfaces adjacent thereto shall be thoroughly cleaned of all scale, rust, grease or oil. A thin film of linseed oil will be permitted for the preservation of machine tool beveled surfaces.

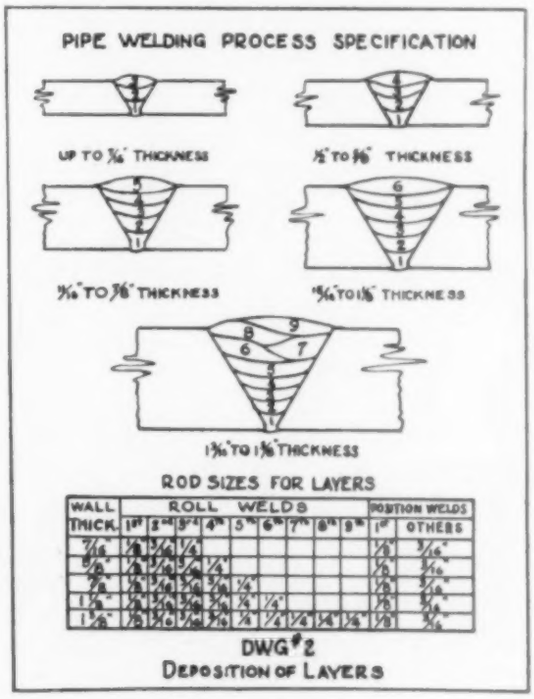
Welding Equipment

Welding torches of an approved type shall be used. Sizes of welding tips to be employed shall be as shown in Schedule No. 1.

Nature of the Flame

The flame used for welding shall be neutral ranging to a slight excess of acetylene.


PIPE WELDING PROCESS SPECIFICATION
MACHINE TOOL BEVELS
MACHINE TORCH BEVELS
S= SPACING 3/16" AFTER TACKS HAVE COOLED
NOTE:- SPACING BEFORE TACKING DEPENDENT UPON SIZE & NUMBER OF TACKS.
MACHINE TOOL BEVELS
MACHINE TORCH BEVELS
DWG. #1
BEVEL PREPARATION



WALL THICK.	ROLL WELDS 1st	2nd	3rd	4th	5th	6th	7th	8th	9th	POSITION WELDS 1st	OTHERS
3/16"	1/8	1/8	1/8							1/8	3/16"
5/16"	1/8	1/8	5/32	1/4						1/8	3/16"
7/16"	1/8	1/8	5/32	5/32	1/4					1/8	3/16"
1/2"	1/8	1/8	5/32	5/32	1/4	1/4				1/8	1/4"
1 5/8"	1/8	1/8	5/32	5/32	1/4	1/4	1/4			1/8	1/4"
1 7/8"	1/8	1/8	5/32	5/32	1/4	1/4	1/4	1/4	1/4	1/8	5/16"

Fig. 5—Expansion Loops on 3-Inch Carbon-Molybdenum Steel Pipe Oxyacetylene Welded

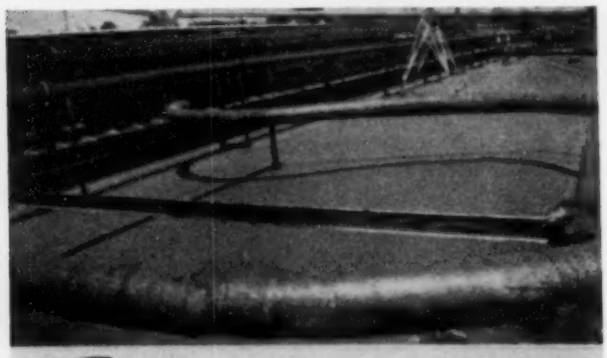


Fig. 6—A Group of Typical Field Test Specimens from 10 x 7/8-Inch Carbon-Molybdenum Pipe

Method of Welding

The method of welding shall be "forehand" or "backhand" as the position of work indicates most expedient.

Definitions.—Forehand welding is that method of welding in which the torch flame and welding rod are so disposed that the flame points ahead in the direction of welding and the rod precedes the flame.

Backhand welding is that method of welding in which the torch flame and welding rod are so disposed that the flame points back at the completed weld and envelopes the molten puddle, and the rod is interposed between flame and puddle.

Number of Layers and Method of Deposition

The number of layers of weld metal shall be as shown in Drawing No. 2.

The size of welding rods to be used shall be substantially as indicated in Drawing No. 2.

For horizontal pipe rolling welds and for vertical pipe position welds, each layer shall be deposited in a continuous circuit of the pipe. When vertical pipe position welds are in difficult positions the method of deposition of layers may be varied but shall conform substantially to that given below for horizontal pipe position welds.

For horizontal pipe position welds each layer shall be started at the top center line and progress downward to the bottom center line. It shall then be restarted (exercising proper precautions to insure fusion at this point) at the top center line and progress downward, on opposite side, to bottom center line where it meets and is fused with previous deposit.

Cleaning of Weld

Each layer shall be wire brushed for removal of loose scale before laying down next successive layer of welding.

The question of stress relieving is one which cannot be ignored in any consideration of carbon-molybdenum steel welding since it is generally recommended by the manufacturers of the pipe material. Standard procedures employed under present fabricating conditions usually require stress relief at temperatures of 1100–1200° F. and maintenance of this temperature for varying periods, from one hour to four hours per inch of thickness. Electric resistance and induction heating methods have been extensively employed. Investigation has disclosed that other methods of heat application will yield equally satisfactory stress relief.

Current code requirements require heating to 1100–1200° F. for at least one hour per inch of thickness. This may be accomplished with an oxyacetylene torch or torches, depending on size and thickness of the joint. From an economical standpoint, however, this is practical only with a relatively small number of joints as usually encountered in the field. In an extensive field operation it has been found more practical to employ burners equipped to use low temperature fuel gas and compressed air. A different size burner is required for each size of pipe.

Schedule No. 1—Size of Welding Tip

Pipe Wall Thickness, Inch	Use Tips Consuming Following Volume of Acetylene—Cu. Ft. Per Hour—Approx.
1/8–1/4	12–36
3/16–1/2	36–60
5/8–7/8	30–100
5/16–1 1/8	50–175
1 1/4–2	65–175

NOTE: In general larger tips of a range (greater acetylene flows) will be used for rolling welds while smaller tips (lesser acetylene flows) will be used for position welds.

Fig. 7—Side Bend Test Specimens. Bent in a Guided Bend Test Jig

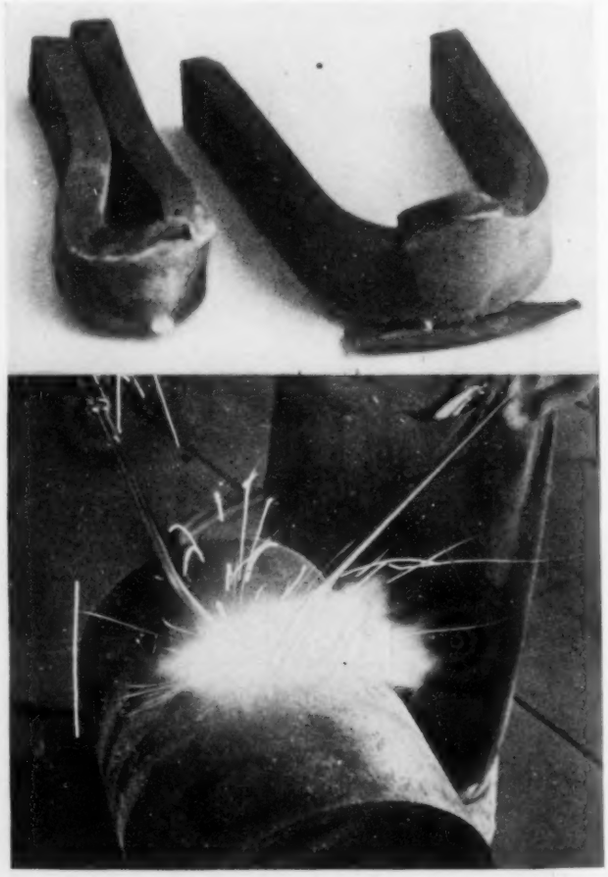


Fig. 8—Welding 14 x 0.75-Inch Wall Carbon-Molybdenum Steel Pipe Joint

Stress relieving with gas flames permits of tapering off the heat-affected zone so as to avoid any sharp difference between stress-relieved and non-stress-relieved areas. Temperature control is obtained through use of Pyrometers, the most common in use now being the contact type. If necessary temperature recording instruments and thermostatic control can also be installed.

Still another method of stress relief which offers much promise has been employed to a limited extent. For want of a better name it has been designated as "short time stress relief" to distinguish it from the other methods. In this procedure after the weld has cooled to say 600° F., the pipe weld and the necessary zone of adjacent base metal is heated uniformly with one or more torches to a temperature range of 1400–1500° F. This is on the basis that this is the closest approach to ideal annealing conditions obtainable in field work. When this temperature is reached as determined by pyrometers, the joint is immediately wrapped with asbestos paper or blankets and any opening plugged up to eliminate interior drafts. This provides slow cooling which is essential. Tests have shown that temperature difference between the outside and inside of a pipe will be about 50° F. but never any greater than 100° F. By utilizing two or more torches, depending on size and thickness, equipped with multiple flame tips if necessary, it is possible to achieve a very uniform heating. This method was first used on a plain carbon steel piping system on both shop and field welding and tests of joints treated in this manner showed greatly refined grain structure and high ductilities when subjected to bending. All but one of the field tests included in the summaries given above were stress-relieved by this method and the results by present standard practices were no better than those by short time stress relief. The photomicrographs shown in Fig. 4 were made of a weld stress-relieved in this manner. All tests conducted to date indicate that this method produces entirely acceptable results.

There has been much discussion of late as to the benefits to be derived from stress relieving, some engineers having gone as far as saying it is not at all necessary. It is not the intention to take sides in this controversy but rather to indicate that a simpler, less expensive means is available in short time stress relief. Since the only practical means of determining the value of these heat treatment methods is by investigation of the grain structures of welds and measurement of ductility either by bending or in tensile tests it is submitted that short time stress relief meets the requirements now demanded of other procedures as witness the test results tabulated.

Independent tests of the relative costs of stress relieving by the various methods indicate that heating with either the oxyacetylene torch or low temperature fuel gas and air flames is slightly less costly than the other standard methods. Short time stress relief is appreciably cheaper than any of the methods noted. Added to this are the advantages of portability and flexibility of the equipment plus the fact that oxygen and acetylene are invariably available on construction work.

On the basis of this work we can now recommend the oxyacetylene welding of carbon molybdenum steel pipe in any of the sizes and weights currently employed in power plant practice. The requisites for successful application are; first, the welding rod of the carbon molybdenum analysis designed for oxyacetylene welding; and second, the use of the multilayer welding technique modified as indicated. Third, the employment of stress relief by any of the methods mentioned.

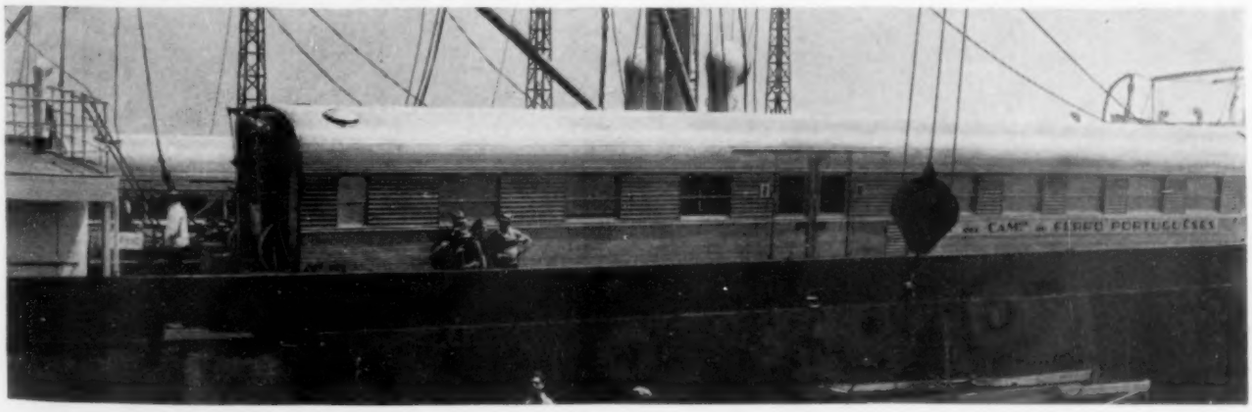
ACKNOWLEDGMENTS

The writer wishes gratefully to acknowledge the cooperation of Mr. Eric R. Seabloom, Research Engineer of Crane Company, Chicago, Mr. P. T. Onderdonk and Mr. E. J. Wiseman of the Consolidated Edison Company, New York City, and, Mr. R. R. Stuart of National Valve and Manufacturing Company, in conducting field tests and making available much of the data used herein.

American "Streamliners" for War-Torn Europe

SAFE delivery of 28 stainless steel railway cars to the Portuguese National Railway was announced on July 16th by the Edward G. Budd Manufacturing Company, as word reached this country that the Franco-Iberian Line freighter, "Cypria," carrying the last of the shipment, had docked safely in Lisbon.

The first "streamlined" type cars built in this country for export, the shipments were made from Philadelphia under strict secrecy in order to lessen the hazards of the ocean crossing. Embodying the same construction principles used by Budd in lightweight trains built for American railroads, the cars are luxuriously equipped for passenger travel between Lisbon, Oporto and Irun, on the French border.



American-Built Streamlined Railway Cars Being Loaded Aboard the Freighter "Cypria" for Shipment to Portugal

APPLICATIONS FOR PULSATION

Welding Broaden the Field of Resistance Welding*

By H. C. COGAN† and R. S. PELTON‡

PART III

IT MAY be well to repeat the definition of Pulsation Welding as described in the two previous articles: "Pulsation welding is a resistance welding method wherein the welding current 'or heat' is applied repeatedly for the making of a single weld, or simultaneous welds, in parts clamped between electrodes at rest when a single like impulse of the same current is not sufficient to produce the desired weld."

Pulsation welding as applied to production jobs is being recognized as an increasingly important process. The advantages already described, especially with spot and projection welding, on small as well as large work, are:

1. Increased electrode life.
2. Thicker material can be welded in production than was practical before.
3. Thicker material can be welded with the same equipment.
4. Better welds are produced in many cases.
5. Any tendency of the weld metal to "spit" or "spash" is noticeably reduced by interrupting the current flow.

It was stated in a previous article that pulsation welding would improve the finished appearance of a resistance weld. This factor was most important in the butt welding of a torque tube assembly to a differential carrier for a well known motor car, both parts being finish machined all over prior to being welded. In other words, the weld was the last operation before the assembly to the car. Therefore, the weld has to be made without a bit of flash or loose particles, and, further, held to the minimum of machine finish tolerance.

The work was equivalent to welding the ends of two pieces of $3^3/_8$ in. diam. x 0.10-in. wall tubing, and pulsation welding, after several trial samples were welded, was the only method that showed any possibility of desired results in production.

The final machine used and placed in production is shown in Fig. 1 and is essentially a vertical, hydraulically operated, butt welder with air-operated, current-conducting clamps and a lower locating fixture for the carrier and an upper center locator for the tube. Two-stage welding pressure was used and the welding transformer was a nominal 300 kva. and operated on 440 volts, 60 cycles.

Full synchronous electronic timing control was used, with automatic and adjustable sequence panel for pulsation welding control.

The timing sequence used for the production run was a total of eight impulses, the first being 28 cycles "on" and 18 cycles "off;" then seven impulses, all 4 cycles "on" and 18 cycles "off." The welding pressure was 4500 lb. for the first six impulses, then jumped to 7500 lb. for the 7th and 8th current impulses.

No current readings were taken, the transformer being operated at about 75% of full capacity, and the production was 150 per hour.

In over a year's production, this job can boast of no weld failures in any of the operating tests the cars were subjected to, at intervals during the production. Being one of the pioneer pulsation welding jobs, it showed that:

1. Costly finished machine parts can be production welded eliminating flash and loose particles with conse-

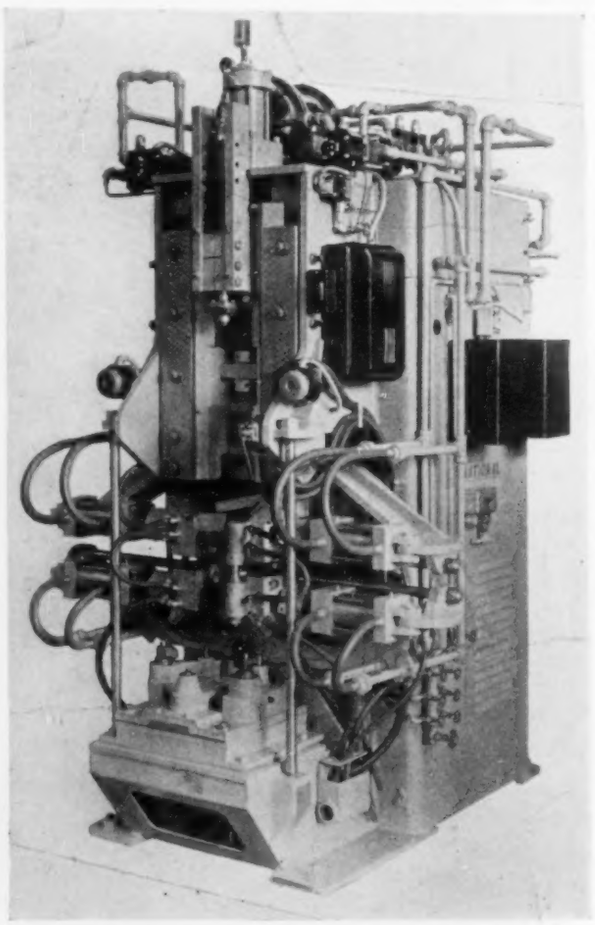


Fig. 1—View of Machine Used in Production of Torque Tubes

* This is one of a series of articles being sponsored by the Resistance Welder Manufacturers' Association.

† Chief Engineer, National Electric Welding Machines Co.

‡ General Electric Company.

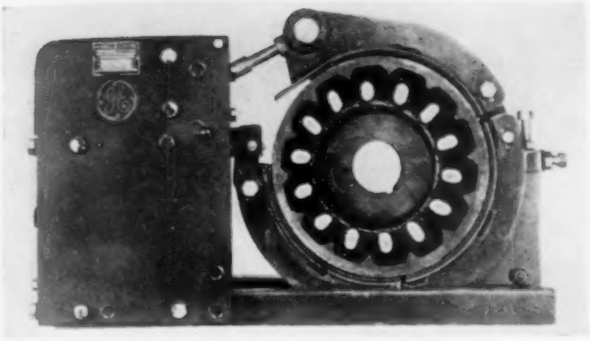


Fig. 2—G-E 3 Shoe Magnet Brake, Side View

quent cleaning operations eliminated. The average tube dimensions after weld were $3^{3}/_{16}$ I.D. x $3^{9}/_{16}$-in. O.D. at the weld line.

2. Close tolerance as to over-all length of finished welded dimensions can be obtained by pulsation welding.

3. No sacrifice of weld or part strength is necessary with pulsation welding for the described finished weld appearance and close tolerance of welded assembly.

Space here will not permit a detailed description of the many welding operations depending entirely on the better results obtained through pulsation welding.

One of the outstanding benefits obtained through pulsation welding is the spot welding of large frame assemblies. Due to the size of these frames, portable resistance welders (Gun Welders) must be used, with their definite limitations as to size, for portability and operation. The stock to be welded consists of two and three thicknesses of $^{1}/_{8}$-in. up to $^{3}/_{8}$-in. structural steel; this being beyond the capacity in work thickness of the usual easily handled portable welder using single current application, more costly means of fabrication was used. However, with pulsation current control, this job (like any portable job up to two pieces of $^{3}/_{8}$ in. thick mild steel) is being very satisfactorily production welded, with welding units easily handled and with considerable savings in costs.

All material is cleaned of rust and scale for these jobs, and plenty of water is used to keep the electrodes and cables cool.

Hydraulic pressure boosters are used to apply 2700 to 3000 lb. pressure on $^{1}/_{2}$ in. diam. electrodes for all thicknesses of steel.

The flexibility of such equipment is illustrated by the fact that a "gun" may be used to spot weld $^{1}/_{8}$ to $^{1}/_{8}$-in. sheet steel with 5 impulses of 15 cycles "on" and 10 cycles "off," then with all other factors the same, weld $^{3}/_{16}$ to $^{3}/_{16}$ in. using 10 impulses of 20 cycles "on" and 10 cycles "off." This is done with about 30,000 amps. of welding current. Then, using the same pressure and interrupter settings with 15 pulsations of 42,000 amps. $^{1}/_{4}$ to $^{1}/_{4}$-in. frameworks are spot welded together.

The values are typical, but the number of pulsations required varies with the set-up and fit of the parts.

Some tabulated results taken at random from Pulsation Spot Welding Data is shown in Table 1.

It must be realized that mild steel has a wide plastic range for suitable welding results. It is known that clean mild steel can be welded at comparatively low temperatures and high pressure or with high temperatures and low pressure, and the tabulated results do vary in this respect. The irregularities in these data are the result of different people's work on different machines.

On Job 4, "4 × 8" pulsations means that the control was set for eight automatic pulsations and was refired four times by push button.

Jobs 9 and 10 are illustrated by Fig. 2 where five spot welds are shown. A 2 in. diameter flat tip was used against the bars to avoid marking and deformation while a $^{7}/_{8}$ in. diameter conventional tip contacted the plate.

Job 11 is illustrated by the etched sectional view, Fig. 3 which shows a good distribution of heat.

Jobs 16 and 17. These figures may not be the ultimate, but gave very satisfactory results. The grain structure in the welds appeared finer and the welds were more solid and stronger than obtained with single impulses of power. It seems reasonable that cooler electrodes would pick up less aluminum but no data was collected regarding this point. Job 17 used a flat tip opposite a cone.

A large narrow strip job was recently met with when a $^{5}/_{16}$ x 1-in. steel strip in the form of a large ring was to be spot welded to a plate steel part $^{5}/_{8}$ in. thick. In this case a larger flat electrode was used against the $^{5}/_{8}$-in. material to make final dressing unnecessary but a better heat balance would probably have resulted if $^{5}/_{8}$ in. diam. tips had been used on both sides.

Table 1—Welding Technique Pulsation Spot Welds

Job No.	Tip Diam., Inches	Static Pressure Lb.	Amps.	Cycles On	Cycles Off	Number of Pulsations	Material
1	$^{3}/_{8}$	430	16,000	4	2	8	$^{1}/_{8}$ to $^{1}/_{8}$-in. steel sheet
2	$^{2}/_{4}$	2,600	37,000	5	5	10	$^{1}/_{4}$ x 2-in. steel bars together
3	$^{3}/_{4}$	4,000	42,000	7	7	17	$^{3}/_{8}$ x $2^{1}/_{2}$-in. steel bars together
4	1	11,500	73,000	20	50	4 × 8	1 x 3-in. steel bars together
5	$^{1}/_{2}$	1,000	20,000	10	9	13	$^{1}/_{4}$ x 2-in. st. angles together
6	$^{1}/_{2}$	2,850	32,000	9	14	9	$^{1}/_{4}$ x 2-in. st. angles together
7	$^{7}/_{16}$	1,350	13,300	13	16	5	0.093-in. clip to $^{3}/_{16}$ x 1-in. steel bar
8	$^{3}/_{4}$	4,000	45,000	20	50	6	$^{1}/_{8}$ + 1 + $^{1}/_{8}$-in. st. plates
9	$^{7}/_{8}$ & 2	7,000	70,000	9	20	3 × 10	$^{1}/_{4}$ plate to $^{3}/_{4}$ x 3-in. steel bar
10	$^{7}/_{8}$ & 2	7,000	73,500	9	20	6 × 10	$^{1}/_{4}$ to 2 x 3-in. steel bar
11	$^{5}/_{8}$	4,000	36,000	11	8	10	$^{1}/_{8}$ + $^{1}/_{4}$ + $^{1}/_{2}$ + 1 + $^{1}/_{4}$ + $^{1}/_{8}$ in. x 2 steel bars
12	$^{5}/_{8}$	5,500	64,000	11	5	7	117 .044-in. steel laminations
13	$^{2}/_{4}$	3,300	58,000	13	31	5	19 $^{1}/_{8}$-in. sheets st. stacked
14	$^{5}/_{16}$	1,500	21,800	10	6	3	2 sections $^{3}/_{32}$-in. Zamac No. 3
15	$^{11}/_{16}$	4,000	86,000	22	50	4	$^{1}/_{2}$ x 2-in. bars 65–35 brass together
16	8° cones	1,200	35,000	4	2	6	$^{1}/_{8}$ to $^{1}/_{8}$-in. Duralumin
17	$1^{1}/_{2}$ in. & 15°	2,200	56,000	5	2	12	$^{1}/_{4}$ to $^{1}/_{4}$-in. Duralumin

Mallory No. 3 or Elkaloy "A" electrodes used.
Cycles of current flow 60 per second alternating current.
All surfaces clean. Heavy scale removed by steel grit blast.

Table 2—Pulsation Projection Welding Technique

Job No.	Projection	Electrodes	Pressure Lb.	Amps.	Cycles On	Cycles Off	No. Impulses
1	1 5/16 in. diam. x 1/16 in. high ring on nut to 1/16-in. sheet steel	Copper Pocket Flat Mal. No. 3	5400	71,000	2	2	4
2	8 proj. 0.040 x 5/32 x 7/16 in. on 3/16 x 1 in. bracket to 1/8 x 1-in. steel ring	Elkonite Trodaloy No. 1	1600	83,000	5	3	8
3	Brass to steel cross 5 Ga. wire	Notched Elkaloy	400		2	4	4
4	Brass 3/16 in. diam. wires crossed	Notched Elkaloy	400		3	3	6
5	0.012 x 1/4 in. diam. in Red Brass to steel	Elkonite	550	13,200	5	2	5
6	0.010 x 11/32 in. ring in 0.020 in. steel to 1/32 x 5/16 in. ni. silver strip	Elkonite	295	16,400	3	11	12

One 5/8 in. diam. tip was used with 2400 lb. pressure and 34,000 amps., "on" for 6 cycles and "off" 24 cycles. The number of pulsations used varied from 40 to 60, depending on shunt currents as 16 welds were made starting with 4 scattered ones to locate the ring and then the spaces were filled in. Due to maintaining cooler electrode surfaces, this and smaller strip jobs have been welded with much less "mushing" or deformation than would otherwise have been possible. This is the reason for the long "off" time.

Table 2 shows similar tabulated results using pulsation welding for some projection welding jobs.

Job 1 is one example of a very common design. It has been found that 20,000 amps. per lineal inch of ring projection and 1000 to 1200 lb. pressure per linear inch is a good general guide for these ring projection jobs for mild steel. It is evident and natural that pulsation welding tends to develop more uniform heat with less power than a single impulse—where one section of the ring is apt to get much more heat than some other section.

On Job 2 much experimenting was done before a dependable, strong weld was obtained. Four projections are located each side of the joint in the ring, and pulsation current control now sets all the eight welds down practically alike; a result which was never obtained without using pulsation control.

Jobs 3 and 4. No current readings were taken, but compared with the welds made with a single current impulse, these welds listed showed more strength.

On Job 5 this single projection gave more dependable results than spot welding.

For Job 6 the general design of the parts placed several limits on the welding possibilities here. This method produced some splash but a strong weld.

A recent job involved the spot welding of a structure of 1/16-in. sheet aluminum to a cast aluminum hub 6 in. thick. Eight spot welds were made very satisfactorily on a 6 3/8-in. circle using 40,000 amps. and 1400 lb. on domed electrodes with 6 pulsations of 7 cycles "on" and 9 cycles "off."

Suppose you have to choose the settings for a job quite different from any previously described. With automatic controls you have to preset the "off time." The first conception was to choose a certain ratio of "off" to "on" time depending on the material and its thickness. For example, with steel it was deemed proper to use equal times "on" and "off" for 1/4 and 3/8-in. stock, with a smaller portion of the time "off" on thinner steel and a greater ratio of the time "off" on thicker steel. This rule served well but it is not the whole story. Its weakness was recently illustrated while working with 3/16-in. duralumin. Because of the high thermal conductivity, a ratio of 3 "on" to 1 "off" was chosen. The times were gradually increased from 6 cycles "on" with 2 cycles "off" to 24 cycles "on" with 8 cycles "off" to see the effects. It was found that a single impulse of 24 cycles gave a weld very similar to that obtained by repeating, showing that the weld zone cooled quite thoroughly dur-

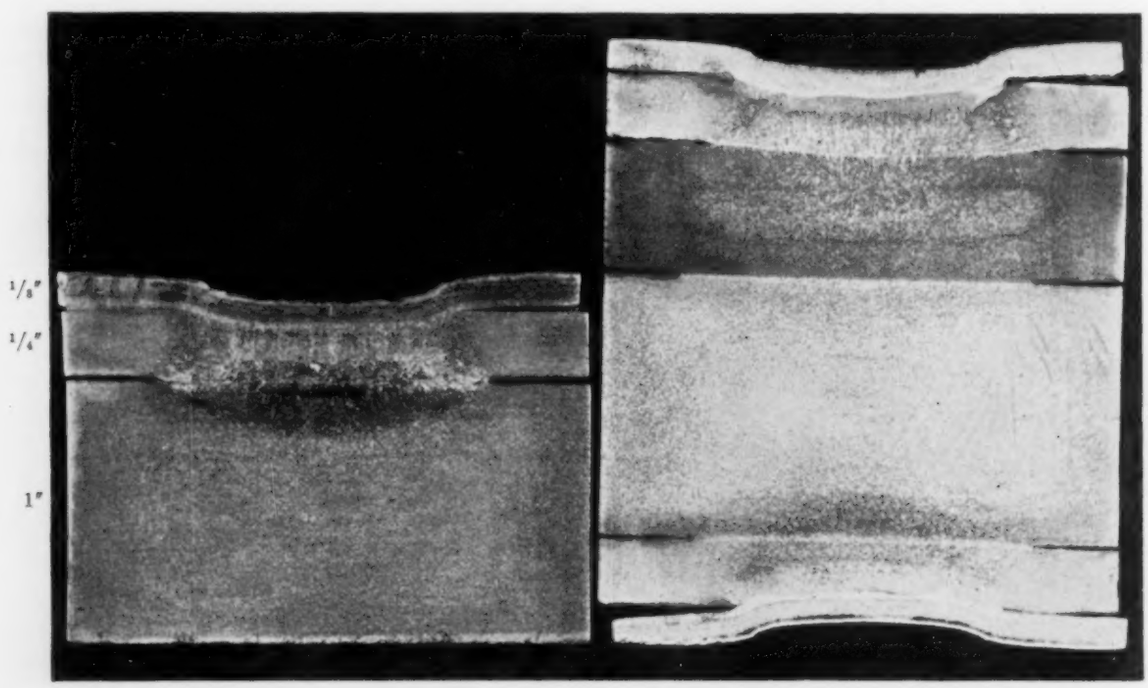


Fig. 3—Etched Section Showing Distribution of Heat

ing 8 cycles "off" which proved to be too long. With thicker steel one can judge quite well from the color changes as to what is taking place, but with metals like zinc and aluminum, you have to judge more from results. The ideal timing would keep the electrode contract surface cool without cooling the weld zone. Try to pick the best compromise.

CONCLUSION

It must not be interpreted that pulsation welding will be a cure-all for all resistance welding problems—too many unique or new methods in resistance welding machines and control have already assumed this responsibility, to the disappointment of users. In time these assumed their proper place in the art, and so too will pulsation welding in time, and with more experience in its use, have a definite place in the resistance welding field, aiding in enlarging the use of this fast growing process of metal fabrication.

WELDING METALLURGY

By O. H. HENRY and G. E. CLAUSSEN

A series of lectures prepared for presentation in a fundamental course of metallurgy and metallography at Polytechnic Institute of Brooklyn under the joint auspices of the Institute and the New York Section of the AMERICAN WELDING SOCIETY. To be published serially in The Welding Journal. Available in Pamphlet Form—47 pages, Journal Size. Copiously Illustrated. $1.00 per copy. Special Prices quantity lots ten or more.

Part IX—Rate of Cooling

In the introductory chapter on "Temperature Changes During Welding," four important factors were set forth as determining the changes in a metal during welding.

1. Rate of heating.
2. Maximum temperature attained.
3. Length of time the maximum temperature is maintained.
4. Rate of cooling.

Of these, rate of heating has little effect on the structure, although too rapid heating may give rise to high thermal stresses and cracks. Factors 2 and 3 were discussed in the sections on the single-pass welds.

In these sections the rate of cooling was assumed to be slow in order that we could use the equilibrium diagram. As a matter of fact, most of the welding that is performed on mild steel is under conditions such that rate of cooling is immaterial. In other words, we have mastered the elementary metallurgy of the welding of mild steel. Before we can appreciate the difficulties that often accompany the welding of higher-carbon and alloy high tensile steels, we must discover what happens to these steels when they are cooled at different rates.

To start with, we inquire what difference it makes whether we cool the weld melt rapidly or slowly. The answer is: comparatively little difference under most circumstances. The faster the weld melt is cooled, the greater tendency it has to undercool to the extent of a few degrees Centigrade. Accordingly, the grain size of the solidified weld will be smaller at fast rates of cooling than at slow. The faster the weld is frozen, the greater the tendency to trap slag (inclusions) and gas (blowholes).

If the metal we were welding underwent no transformation after freezing, the rate of cooling would have no effect on structure, although it would affect shrinkage stresses. Rate of cooling becomes vital only if, as in iron, the metal undergoes a change in crystalline form during cooling, for it is a characteristic of transitions that they tend to undercool. That is to say, at fast rates of cooling, the crystal, stable above the transition temperature, may not change, if at all, until a comparatively low temperature has been reached. Since the transformation from austenite to ferrite occurs at temperatures not above about 900° C., rate of cooling has no effect on the crystals of austenite from the solidus temperature down to about 900° C. Below about 900° C., however, cooling rate has a paramount influence on the structure of any steel.

We shall discuss the effect of cooling rate on the same mild steel containing 0.20% C that was welded in the preceding sections. Steels of any other carbon content behave basically the same as mild steel, except that (1) the upper critical point varies with the carbon content, (2) the rates of cooling required to cause the peculiar undercooling effect in steel become slower as the carbon content is increased and (3) cementite instead of ferrite is the first material to separate from austenite containing over 0.80% C during slow cooling.

The mild steel is at 900° C., shown at X in the iron-iron carbide equilibrium diagram, Fig. 63. It consists of austenite crystals containing 0.20% C. As we cool slowly at a rate of 1° C. per min., for example, the ferrite crystals (nearly pure iron) form at 850° C. (A_3) and continue to grow, until at 750° C., the austenite occupies only $\left(\frac{a}{a+b} \times 100\right)$ % of the structure and contains about 0.7% C (see section on the Weld Melt (Steel)). The rest of the steel consists of ferrite crystals at 750° C.

Instead of slow cooling from 900 to 750° C., let us cool the steel extremely rapidly, and assume that the piece of

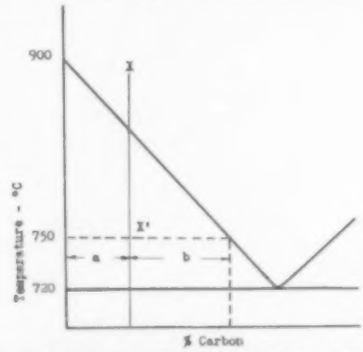


Fig. 63—Portion of the Iron, Iron Carbide Equilibrium Diagram, Showing the Change in Composition of Austenite During the Slow Cooling of a Mild Steel Through the Critical Range

steel is small, such as a fine wire, so that at any instant the temperature is everywhere the same. To be precise, suppose we cool the steel from 900 to 750° C. in a millionth of a second. We find that at the instant the steel reaches 750° C. it is still 100% austenite, Fig. 64. As we watch the steel at 750° C. with our microscope, we see no change in the undercooled austenite for some time. Suddenly, tiny crystals of ferrite appear. During a further period of observation, the ferrite crystals grow and more appear. After the ferrite crystals have replaced the amount of austenite dictated by the equilibrium diagram, there is no further change. The amount of ferrite and austenite in the steel at 750° C. will be the same as after slow cooling. When austenite is undercooled by rapid cooling, therefore, any changes in the austenite obey two rules:

1. Some time elapses before the austenite starts to transform (the incubation period).
2. Some time elapses before the transformation is complete (reaction time).

Fig. 64—During Rapid Cooling from 900 to 750° C. No Ferrite Is Formed. Holding at 750° C. Permits Ferrite Nuclei to Form and the Resulting Ferrite to Grow Until Equilibrium Is Attained

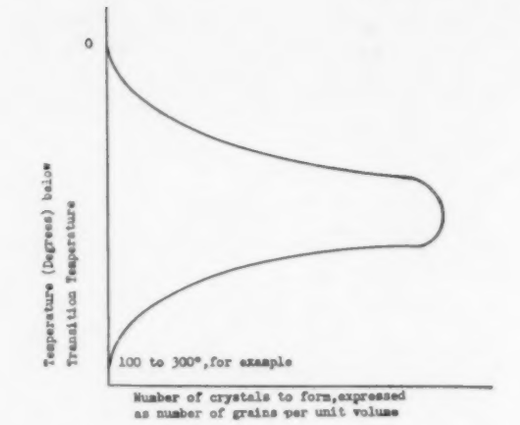
Although the amount of ferrite and austenite in the steel at 750° C. will be the same after extremely rapid cooling followed by holding at 750° C. as after slow cooling, there will be many more ferrite crystals in the former specimen than in the latter. That is to say, each ferrite grain will be smaller in the former specimen. The general rule is shown diagrammatically in Fig. 65. The lower the temperature to which the austenite is undercooled, the more numerous are the resulting crystals to which the austenite transforms, and the sooner the first crystal appears, *unless* the austenite has been undercooled too many degrees below the transition temperature (720 to 900° C., depending on the carbon content of the steel). Further undercooling has the reverse effect, because the atoms are too rigid to transform. Austenite thus behaves like molten glass, which if cooled rapidly below 600° C. does not crystallize even after hundreds of years have elapsed.

Figure 66 records the experimental results on rapidly cooled (undercooled) austenite for all temperatures from the lower critical A_1 to about 200° C. It will be realized that the diagram is schematic only, and omits numerous factors that are still the subject of research. The diagram is based on rapid cooling experiments of the type shown in Fig. 64.

Application to Welding

Consider three examples.

1. The austenite is cooled extremely rapidly (in 0.001 second, for example) from 900° C. to just below Ac_1 (720° C.). After many hours at 700° C., a crystal of cementite separates from the austenite, time T_1. At once, ferrite crystals also appear to form the nucleus of a pearlite grain. During several additional hours the ferrite and pearlite grains grow, until at time T_2 all the austenite has changed to pearlite. (For simplicity the ferrite that should separate between A_3 and A_1 is omitted from consideration.) The plates of cementite and ferrite in the pearlite will be large, and the pearlite grains as a whole will be large.
2. The austenite is cooled extremely rapidly (in 0.001 second, for instance) from 900 to 600° C. After


0
Temperature (Degrees) below Transition Temperature
100 to 300°, for example
Number of crystals to form, expressed as number of grains per unit volume

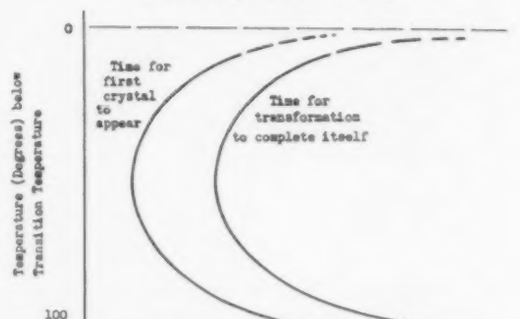

0
Temperature (Degrees) below Transition Temperature
Time for first crystal to appear
Time for transformation to complete itself
100 to 300°
Time for first crys tal to appear and for transformation to complete itself

Fig. 65—Upper Diagram—Schematic Diagram Illustrating the Effect of Undercooling on the Number of Crystals That Are Formed
Lower Diagram—Corresponding Diagram Showing the Effect of Undercooling on the Time Required for the First Nucleus to Form, and the Time for the Nuclei to Complete Their Growth

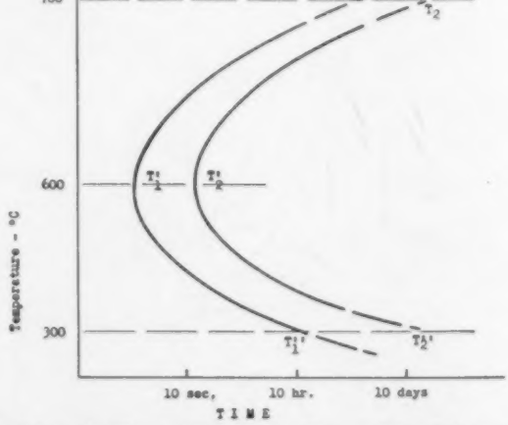


Fig. 66—Schematic Diagram Showing the Change of Austenite to Ferrite and Carbide at Different Temperatures Below the Critical Range. The Scales Are Purposely Out of Proportion to Emphasize the Fact That the Diagram Is Schematic Only, Not Quantitative

or 2 seconds at 600° C. (time T'_1) cementite and ferrite crystals start to appear, and after another few seconds all the austenite has completed the change to pearlite. T'_2 seconds after the austenite is cooled it has transformed completely to pearlite. Each pearlite grain is small, and each plate of cementite and ferrite is correspondingly small. If, instead of 600° C. the temperature had been somewhere between 600° and 720° C., the resulting pearlite would have been of intermediate fineness. The strength and hardness of pearlite increases as the grains and plates become finer. The fine pearlite formed at 600° C. may be twice as hard and strong as the coarse pearlite formed at 710° C.

3. The austenite is cooled extremely rapidly from 900 to 300° C. After several hours, T''_1 the austenite starts to transform, but to a different product from pearlite, called Bainite. After a period of time T''_2 the austenite has transformed completely to bainite. Little is known about bainite and we shall not discuss it further, except to point out that under exceptional circumstances some regions in an alloy steel weld may be cooled rapidly to about 300° C. and may be maintained at that temperature by a succeeding bead in which event bainite might form, as it might also under exceptional circumstances in steel preheated to 300° C.

In Fig. 67 there are plotted the temperature changes at three different points in the heat-affected zone during the cooling of a hypothetical weld in steel. The temperature at point III is falling slowly, whereas at point I the rate of cooling is rapid. On the diagram the points T'_1 and T'_2 from the preceding diagram are plotted. The steel at point III obviously will be pearlite at 600° C., whereas at point I the steel will still be austenite. At point II the steel probably will be mainly pearlite (finer than at point one) "probably," we say, because the diagram does not consider a number of factors whose discussion we must forego. Extremely fine pearlite, that is, pearlite in which the ferrite and cementite plates are very thin—not small grains of pearlite—is called *troostite*.

The upshot of the discussion should be clear. As the rate of cooling is increased from slow to fast, the grains of pearlite and plates of cementite and ferrite become smaller, the strength and hardness rise, the ductility decreases. Eventually, we will be in a position to know the rates of cooling in different types of welds and to deduce the mechanical properties therefrom. If the rate of cooling is extremely rapid, austenite will cool below the temperature range of 500–600° C. without transforming in all parts or even without transforming at all in some alloy steels.

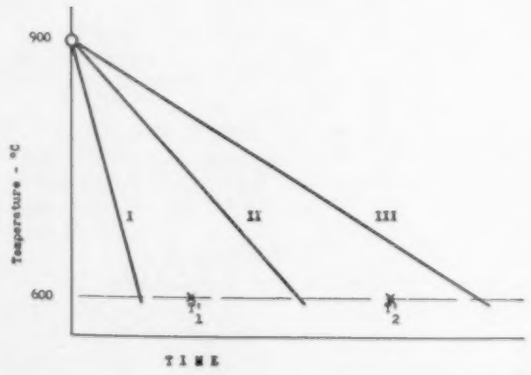


Fig. 67—Change in Temperature with Time During Cooling at Three Points in a Weld

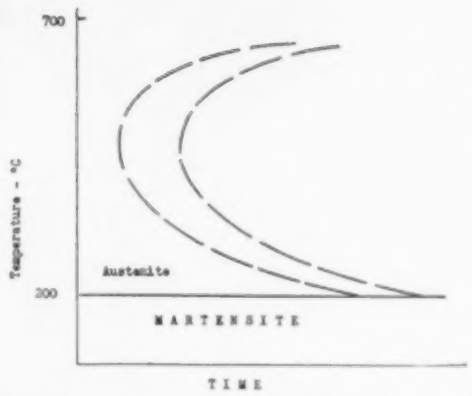


Fig. 68—A Modification of the S-Curve. Often Some Austenite Is Present with Martensite at Room Temperature

Martensite

We now extend our discussion to undercooled austenite at temperatures below 300° C. The austenite that has cooled so rapidly that it has not transformed above 300° C. now cools to room temperature. As it cools through the temperature range, 100–200° C., the austenite suddenly changes to an extremely hard, brittle structure called *martensite*. If we are asked for a definition of martensite, the safest one we can offer is that martensite is the structure formed in steel when austenite transforms below about 200° C. in plain-carbon steels. Our microscope shows that martensite has a needle-like appearance. X-rays disclose that martensite crystals have a different arrangement of iron and carbon atoms than ferrite or austenite. There is an expansion when austenite changes to martensite which may affect shrinkage stresses and cracks, to which martensite is particularly prone.

When martensite is included, our chart showing the behavior of undercooled austenite assumes the form shown in Fig. 68. Below 200° C. austenite in plain-carbon steel always changes to a great extent to martensite, which has the characteristic of fracturing in an intergranular manner.

The intergranular fracture of martensite is unexpected in view of the fact that numerous tiny cracks, often less than 0.0001 inch in any dimension, are found within the boundaries of otherwise sound grains of martensite. Nevertheless, the tiny cracks doubtless accentuate the brittleness of martensite. Little is known about the cracks and, indeed, it is doubtful whether they occur in martensite formed in mild steel or low-alloy structural steel. The intergranular type of fracture is not always observed in martensite. Sometimes transcrystalline cracks are observed in heat-affected zones containing martensite. There is a possibility, of course, that these cracks were formed at a temperature slightly above the temperature at which martensite is formed.

As we increase the carbon content of plain carbon steel, the two curves in Fig. 68 shift to the right. In other words, austenite will undercool below 500° C. with slower cooling rates in high-carbon steel than in low-carbon steel. The more or less complete change to martensite still occurs at 100–200° C., regardless of carbon content. For this reason, welds made in the higher carbon steels (above 0.25% C) tend to crack, unless the base metal is preheated above 100–200° C. The reason for the cracking is related to the effect of carbon content in facilitating the undercooling of austenite, which if undercooled below 500° C. or so,

transforms to hard, brittle martensite below 200° C. When the expansion accompanying the formation of martensite is combined with the shrinkage stresses that are building up in the now rigid steel, at X for example, in Fig. 69, the resulting deformation may crack the brittle martensite. Whether cracks occur depends, of course, on the rates of cooling at all parts of the welded plates that have been heated above the lower critical point during welding. Experience with cracking shows that rates of cooling often occur in practice that are sufficient to force austenite to change to martensite instead of pearlite. The maximum rate of cooling after welding is greater for thick than for thin plates, and increases with increase in the ratio: $\frac{\text{size of heat source}}{\text{welding speed}}$. The tendency to cracking is aggravated by the formation of localized pools of high-carbon austenite in that part of the heat-affected zone which is heated above the lower critical (A_1) but below the upper (A_3).

Preheating prevents cracking in regions containing martensite by preventing the formation of martensite. If the steel is everywhere above 200° C. during welding, it is impossible for martensite to form, because it can form only from austenite below 200° C.

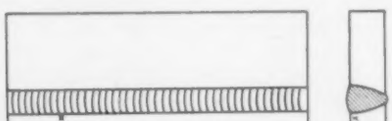


Fig. 69—Possible Location of a Crack in the Heat-Affected Zone

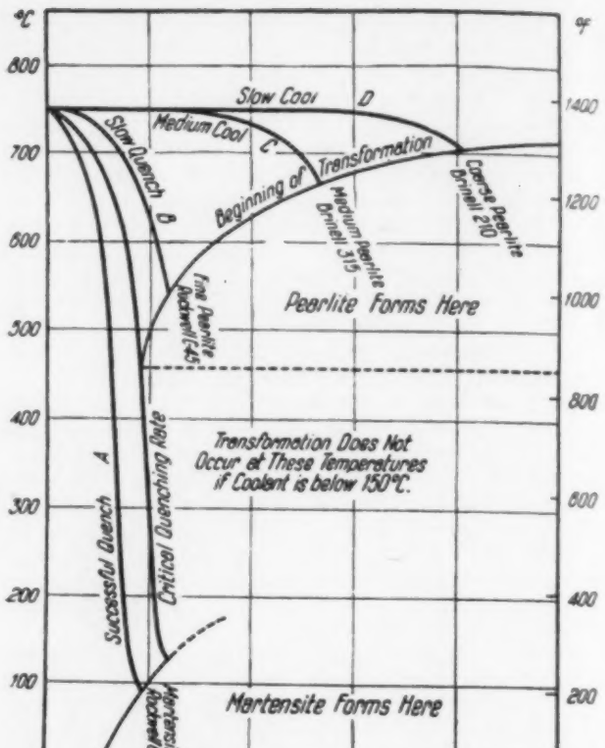


Fig. 70—Influence of Cooling Rate on the Temperature and Product of Transformation in Steel Containing 0.85% Carbon. (E C Bain)

Quenching

Quenching is rapid cooling by immersion in liquids or gases or by contact with metal. The term is applied to the heat-treating operation in which a medium-carbon or high-carbon steel is heated 50° C. above the upper critical (A_3) and immersed in a quenching medium at about room temperature. Immersing the steel in cold brine is known as brine quenching; in oil as oil quenching; in air as air quenching. The steel cools extremely fast during brine quenching, slower in oil quenching, still slower in air quenching.

During brine quenching of a thin section of steel, say $^1/_4$ inch diameter, the austenite is supercooled to 100–200° C., then changes to martensite, and appears to our microscope at room temperature as martensite. The steel is said to be fully hardened. Up to 0.60% C, the hardness of martensite increases from 40 Rockwell C in fully hardened steel containing 0.10% C, through 50 C in fully hardened steel containing 0.20% C; to 66 C in fully hardened steel containing 0.60% C. Beyond 0.60% C the hardness of martensite remains at about 66 Rockwell C.

Oil quenching usually is too slow to fully harden plain carbon steel. Brine quenching cools a thin piece of steel at the rate of over 500° C. per second, while the steel is in the temperature range 450–650° C. in which austenite transforms most rapidly to pearlite. In other words, the steel remains in the range less than $^1/_2$ second, which the S curve shows to be insufficient for appearance of the first particle of pearlite. The austenite continues to cool until at 100–200° C. it is changed to martensite. During oil quenching, on the other hand, the rate of cooling of a thin bar of steel in the temperature range 450–650° C. is only about 50° C. per second. The steel remains in the range about 4 seconds, which is sufficient to permit the austenite to change partly or wholly to pearlite, Fig. 70, with evolution of heat which tends to reduce the cooling rate still further. The higher the carbon content of the steel, the smaller will be the quantity of austenite that will transform. Likewise, the coarser the grain size of the austenite, the less it will transform. Oil quenched plain carbon steel, therefore, is softer than brine quenched, because the latter has no pearlite.

Air quenching usually is so slow that the steel transforms entirely to pearlite during cooling in the range 650–600° C. Of course, a wire cools faster in air than a 1-inch plate, but in all our discussion it is assumed that we are remembering that the surface of a part cools more rapidly than the interior, and that thin sections of uniformly heated metal cool more rapidly than thick. Consequently, air cooling may harden a wire, yet may produce a soft pearlite in a 2-inch plate. Indeed, air cooling of steel $^1/_4$ inch and thicker from 50° C. above the critical is the customary means of creating a strong, ductile structure in steel, and is called *normalizing*.

In welding, the rate of cooling after the weld melt has passed by is governed by contact with adjacent steel rather than by "immersion in air." In the section on the Solid Weld we found that as we moved away from the weld melt we got cooler. That is to say, the temperature fell; heat was being absorbed from the hot regions near the weld by the cold regions farther away. Note that the heat is absorbed by brine or air in heat treating, whereas in welding, experience shows that the major portion of the heat is absorbed by the steel adjacent to the weld before it is lost to the air.

Experience shows also that the cooling rates in the

zones heated above the critical during welding may be high enough to cause undercooling of austenite below 500° C. and to form martensite. A thin bead deposited between thick plates is particularly likely to create martensite in the heat-affected zone. Martensite is also favored by the large size of the austenite grains in the zone adjacent to the weld melt, that has been heated nearly to the melting point. Ordinarily the weld metal is of lower carbon content than the base metal and so is less susceptible to martensite formation than the heat-affected zone.

All in all, the rate at which the different regions of a weld cool through the temperature range from the critical to below 500° C. varies with plate thickness, welding process, and other variables. Full hardening, corresponding with large proportions of martensite in the heat-affected zone, may be created in the heat-affected zone of a spot weld in high-carbon steel sheets, for example. Partial hardening, corresponding with small proportions of martensite in the heat-affected zone, may be created in the heat-affected zone of a thin bead deposited on a thick plate of relatively low-carbon steel, such as 0.30% C. Aside from martensite, the more rapid the rate of cooling, the finer is the pearlite that is formed.

Extremely fine pearlite often is called troostite, which is harder and less ductile than the coarse pearlite formed at higher temperatures, for example 650° C., during slower cooling. Troostite etches most rapidly of all structures in polished sections for microscopic examination. It appears black to the naked eye. Martensite reacts most slowly and often has a yellow color after being etched. Coarse pearlite has the appearance of mother-of-pearl. Besides tending to embrittle steel, rapid cooling accentuates the shrinkage stresses while reducing distortion. "Quenching" of welded joints, therefore, hardens them and creates a structure of low ductility that is especially likely to crack in service, if not during the "quenching" itself.

Reheating the Weld

Frequently, welding must be done under conditions that resemble quenching. The weld cools very rapidly. To remove the shrinkage stresses and to insure against martensite the welded part is *stress annealed* by heating to 600–675° C. (1100–1250° F.). Stress annealing reduces shrinkage stress to a low value (5000 lb./in.^{2}) and removes martensite.

At a given temperature of stress annealing, or, as it is often called, "stress relieving," the longer the duration of heating, the lower are the residual stresses. Another rule is that for a given time at temperature, the higher the temperature of stress annealing (500–600° C.), the more completely are the residual stresses removed. For example, it may require 12 hr. at 1050° F. to reduce the residual stress below 5000 lb./sq. in., whereas at 1250° F. a similar reduction might be achieved in $^1/_2$ hr. The duration of stress relieving often is 1 hr. per inch of the thickest section in the part. For massive parts of uniformly thick cross section, the highest temperature (1250° F.) might be selected for stress relieving. For assemblies consisting of thick and thin parts, on the other hand, a lower temperature creating less scaling and distortion might be advisable.

How does stress annealing remove martensite? Martensite consists of iron atoms in crystalline form with carbon atoms spaced at random among the iron atoms. That is to say, the carbon atoms are in solution. Upon being reheated, the iron atoms change to the alpha (body-centered cubic) form and some combine with the carbon atoms to form tiny globules of iron carbide (cementite). The structure consisting of tiny globules of cementite in ferrite is called *sorbite*.

The operation of reheating hardened steel to a temperature below the critical (A_1) is known as tempering or, less commonly, drawing. Stress annealing, therefore, is tempering performed for the special purpose of removing internal stresses without exceeding the critical temperature (A_1). If there were any martensite in the part before stress relieving it will be changed to sorbite. However, if the martensite contained tiny cracks before stress relieving, the cracks will not be healed. Tiny cracks in martensite are healed only by reheating to a high temperature, such as 1000° C.

Martensite changes to sorbite if it is heated to about 200° C. Why then should stress annealing require 600° C.? The shrinkage stresses are not completely eliminated until 600° C., and the sorbite formed at 200° C. is not sufficiently soft and ductile. As the temperature is raised from 200 to 600° C., the cementite globules grow larger and less numerous; hence, there is less obstruction to slip on the crystal planes of the ferrite. Stress annealing eliminates shrinkage stresses and transforms any martensite that may have been present to sorbite.

Structures in Steel

On Cooling from Above the Critical

Rate of Cooling	Structure
Slow	Coarse pearlite, soft (150 Brinell)
Mild quench	Fine pearlite (troostite), medium hard (300 Brinell)
Drastic quench	Martensite, hard (500 Brinell)
On reheating	Martensite
Sorbite	

Questions

1. Numerically, what rates of cooling through the range 750–350° C. lead to profound changes in the structure of steel?
2. State the differences among pearlite, ferrite, martensite and cementite.
3. What are the conditions which govern the appearance of martensite in the vicinity of a welded joint?

Tentative Rules for FIELD WELDING OF STORAGE TANKS

I—GENERAL

1. *Scope*

a. These rules are intended to apply to the construction of fusion welded bulk storage tanks of the above-ground type for holding liquid products operating generally at atmospheric pressure or at not over 15 pounds per square inch gage pressure.*

b. The rules are intended to prescribe safe welding requirements for such tanks and apply particularly to cylindrical tanks with vertical axes and to elevated tanks, all of such diameters that they cannot be shop constructed and shipped by car or truck.

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c. Two types of structures are included in these rules:

Type A

Tanks operating at atmospheric temperature and at substantially atmospheric pressure, or at a gage pressure not exceeding 27.7 inches of water, or 1 pound per square inch, in the vapor space.

e.g., Bulk storage tanks with flat bottoms, cylindrical shells and gas-tight roofs, for liquids other than water.
Standpipes, reservoirs and elevated tanks, for storage of water.

Type B

Low pressure storage tanks operating at a gage pressure, in the vapor space, not exceeding 15 pounds per square inch.

e.g., Low pressure tanks for bulk storage of liquids and vapors over same, wherein the gage vapor pressure at storage temperature, in the vapor space, is higher than 1 pound per square inch, but not exceeding 15 pounds per square inch.

d. Specifications for the construction of "All Welded Oil Storage Tanks" are covered by American Petroleum Institute's Standards 12-C. Specifications for the construction of "Elevated Steel Water Tanks, Standpipes and Reservoirs" are covered by the American Water Works Association Specifications. The AMERICAN WELDING SOCIETY collaborated in the preparation of these specifications.

* This code is intended for application to vessels subject to lower pressures than those covered by the A. S. M. E. Code for Unfired Pressure Vessels.

Prepared by the Committee on Rules for Field Welding of Storage Tanks and Approved by Executive Committee April 4, 1940

2. *Definitions and Symbols*

a. Welding terms employed in these rules shall be interpreted according to the definitions given in the latest edition of "Definitions of Welding Terms and Master Chart of Welding Processes," issued by the AMERICAN WELDING SOCIETY.

b. Symbols used on construction drawings shall conform to those shown in the latest edition of "Welding Symbols and Instructions for Their Use," issued by the AMERICAN WELDING SOCIETY.

II—MATERIALS

3. *Plates*

These rules cover the use of plate materials conforming to any of the following American Society for Testing Materials Specifications of the latest revision. (In no case, however, shall the carbon content exceed 0.30%, nor the manganese content 1.00%, by ladle analysis.)

*A 7 —Steel for Bridges and Buildings.
*A10 —Mild Steel Plates.
A70 —Carbon Steel Plates for Stationary Boilers and Other Pressure Vessels.
A78 —Steel Plates of Structural Quality for Forge Welding (for fusion welding).
A89 —Low Tensile Strength Carbon-Steel Plates of Flange and Firebox Qualities (for fusion welding).
A113—Structural Steel for Locomotives and Cars (Plates for cold pressing).
A201—Carbon-Silicon Steel Plates of Ordinary Tensile Ranges for Fusion-Welded Boilers and Other Pressure Vessels.

4. *Structural*

These rules cover the use of structural materials conforming to the following A. S. T. M. Specification of the latest revision. (The carbon content shall not exceed 0.30%, nor the manganese content 1.00%, by ladle analysis.)

A7—Steel for Bridges and Buildings.

5. *Copper Bearing Steel*

Copper bearing steel with content of about 0.20% copper may be used when specified. In other particulars the steel shall conform to specifications enumerated above.

6. *Forgings*

These rules cover the use of forgings conforming to the following A. S. T. M. Specifications of the latest revision. (In no case shall the carbon content exceed 0.30% by ladle analysis.)

* Steels marked are those that have been commonly used for storage tank construction.

Bent, Face, and Side Bend Test—Any specimen in which a crack

* Steels marked are those that have been commonly used for storage tank construction.

a. Plate Forgings

A-78 —Steel Plates of Structural Quality for Forge Welding, (for fusion welding).

A-89 —Low Tensile Strength Carbon-Steel Plates of Flange and Firebox Qualities, (for fusion welding).

b. Forgings, Other Than Plate

A-18 —Class *B*—Carbon-Steel and Alloy-Steel Forgings.

c. Forged and Rolled Pipe Flanges

A-181—Class *I*—Forged or Rolled Steel Pipe Flanges for General Service.

7. *Castings*

These rules cover the use of castings conforming to the following A. S. T. M. Specification of the latest revision. (Carbon content not to exceed 0.25% by ladle analysis.)

A-215—Grade A-3-W—Carbon-Steel Castings Suitable for Fusion Welding for Miscellaneous Industrial Uses.

8. *Filler Metal*

a. Electrodes shall conform to the A. W. S.-A. S. T. M. Tentative Specifications for Iron and Steel Arc Welding Electrodes, Serial Designation A 233-40T, using the following classifications:

E-6010, E-6011, E-6012, E-6013, E-6020 and E-6030.

The classification number selected must be suitable for the electric current characteristics and also for the position of welding.

b. Gas welding rods shall conform to the A. W. S.-A. S. T. M. Tentative Specifications for Iron and Steel Gas Welding Rods. The reduced section tensile strength without stress relieving shall be at least equal to the minimum of the A. S. T. M. tensile range of the base material to be welded.

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III—QUALIFICATION OF WELDING PROCEDURE AND TESTING OF WELDING OPERATORS

9. *Application*

Welding procedure shall be qualified and welding operators shall be tested according to the latest rules of the AMERICAN WELDING SOCIETY "Standard Qualification Procedure," using the following values and modifying conditions:

10. *Butt Welds for Primary Stress*

(Joints subject to primary stress due to weight or pressure of tank contents.)

a. Tension Test, Reduced-Section Tension Test—not less than 95 per cent of the minimum of the specified A. S. T. M. tensile range of the base material.

b. Free Bend Test—minimum elongation 20 per cent.

c. Root, Face, and Side Bend Test—Any specimen in which a crack is present after the bending, exceeding $^1/_8$ inch measured in any direction, shall be considered as having failed. Cracks occurring on the corners of the specimen during testing shall not be considered.

11. *Butt Welds for Secondary Stress*

(Joints subject to secondary stress, those not directly affected by weight or pressure of tank contents.)

a. Tension Test—Butt joints which do not require full penetration shall have the procedure qualified by the Reduced-Section Tension-Test only. This test shall not be used for the qualification of welding operators.

b. The Reduced-Section Tensile Test shall give values not less than 110 per cent of the specified strength of the joint.

12. *Fillet Welds*

a. Transverse Shear Test—shall have a minimum value in pounds per square inch equal to seven-eighths ($^7/_8$) of the minimum of the specified A. S. T. M. tensile range of the base material.

b. Longitudinal Shear Test—shall have a minimum value in pounds per square inch equal to two-thirds ($^2/_3$) of the minimum of the specified A. S. T. M. tensile range of the base material.

c. Fillet Weld Soundness Test—Any specimen in which a crack is present after the bending, exceeding $^1/_8$ inch measured in any direction, shall be considered as having failed. Cracks occurring on the corners of the specimen during testing shall not be considered.

d. Double fillet welded lap joints using various size welds, such as used to resist secondary stress, may be qualified with shear tests only, using the unit shear stress values given in Paragraphs *a* and *b*. Such tests shall not be used for the qualification of welding operators.

13. *General*

a. In the case of vertical welding, the procedure shall be qualified and the operator shall be tested using the same direction for welding each pass (either upward or downward progress) that will be used in the construction.

b. Contractor shall submit qualification test reports for the procedure he intends to use, including all types of welded joints, welded in all positions to be used in the construction. These test reports shall bear proper witness certification of a reputable testing laboratory or inspection agency, stating that such tests were performed in accordance with the above mentioned requirements. The tests need not be repeated for every contract.

c. All welding operators assigned to weld on tanks constructed under these rules shall have been tested under the above mentioned AMERICAN WELDING SOCIETY "Standard Qualification Procedure." The contractor shall certify that such tests were performed in accordance with the above mentioned requirements.

d. The operator qualification tests herein specified shall be considered as remaining in effect indefinitely unless (1) the welding operator

has not been continuously employed by the contractor on similar work, using similar welding procedure, for a period of three months or more since making qualification tests; or unless (2) there is some specific reason to question an operator's ability. In case (1) above, the requalification test need be made only in the $^3/_8$-inch thickness.

e. The contractor shall maintain a record of each welding operator employed by him, showing the dates and results of qualification tests and the work-identification mark assigned to him.

IV—DESIGN VALUES

14. *Design Stresses—Fillet Welds*

a. Stress in a fillet weld shall be considered as shear. The values shall be in pounds per square inch of cross section, measured in the throat of the weld. The throat of a fillet weld shall be assumed as 0.707 times the length of the shorter leg of the fillet weld.

b. Transverse Shear—The stress in fillet welds acting in transverse shear, for structural or other attachments, shall be computed as 65 per cent of the allowable working tensile stress of the plate or structural material joined.

c. Longitudinal Shear—The stress in fillet welds acting in longitudinal shear, for structural or other attachments, shall be computed as 50 per cent of the allowable working tensile stress of the plate or structural material joined.

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15. *Welded Joint Efficiencies*

	Type of Joint	Efficiency Per Cent
a.	Double welded butt joint with complete penetration.	85 Tension; 100 Compression
b.	Double welded butt joint with partial penetration and with the unwelded portion located substantially at the middle of the thinner plate.	$85\,\frac{Z}{T}$ Tension; $100\,\frac{Z}{T}$ Compression
	Where: Z is the total depth of penetration from the surfaces of the plate (use the thinner plate if of different thicknesses). T is the thickness of the plate (use the thinner plate if of different thicknesses).	
c.	Single welded butt joint with suitable backing-up strip or equivalent means to insure complete penetration.	85 Tension; 100 Compression
d.	Double-welded lap joint with full-fillet weld on each edge of joint.	75 Tension or Compression

e.	Double-welded lap joint with full-fillet weld on one edge of joint and an intermittent full-fillet weld on the other edge of joint.	$75\left\{\frac{1+X}{2}\right\}$ Tension or Compression
	Where: X is the percentage of full-fillet intermittent welding, expressed as a decimal.	
f.	Lap joint with full-fillet welds, or smaller, on either or both edges of the joint, welds either continuous or intermittent.	$75\left\{\frac{XW_1 + YW_2}{2T}\right\}$ Tension or Compression
	Where: X and Y are percentages of intermittent welds for welds W_1 and W_2 respectively, expressed as a decimal. W_1 and W_2 are the sizes of the welds on each edge of the joint, respectively. (W_2 will be zero for a joint welded on one edge only.) T is the thickness of plate (use the thinner plate if of different thicknesses).	

V—JOINT DESIGN

16. *Butt-Welded Joints Subject to Primary Stress from Weight or Pressure of Tank Contents*

e.g. Vertical joints of cylindrical tank shells, type *A* tanks.
All joints below the point of support in suspended bottom, type *A* tanks.
All joints in low pressure, type *B* tanks.
(Does not apply to roofs of type *A* tanks subject to vapor pressure only.)

These joints may be double welded to insure complete penetration, or they may be single welded with suitable backing-up strip or equivalent means to insure complete penetration.

17. *Butt-Welded Joints Subject to Secondary Stress*

e.g. Horizontal joints of cylindrical tank shells, type *A* tanks.

These joints shall be designed to develop an efficiency of at least 57 per cent, based on the thickness of the thinner plate joined. They shall be double welded and may have partial penetration (at least two-thirds penetration required) with the unwelded portion located substantially at the middle of the thinner plate. (This joint shall be at least equivalent to two-thirds that of a double welded butt joint with full penetration.)

18. *Lap-Welded Joints Subject to Primary Stress from Weight or Pressure of Tank Contents*

e.g. Vertical joints of cylindrical tank shells, type *A* tanks.
All joints below the point of support in suspended bottom, type *A* tanks.

23. *Unsymmetrical Butt Joints*

full-fillet weld on each edge of joint.

All joints below the point of support in suspended bottom, type *A* tanks.

All joints in low pressure, type *B* tanks.
(Does not apply to roofs of type *A* tanks subject to vapor pressure only.)

These joints shall have continuous full-fillet welds on both sides of the joint.
(Maximum thickness permitted for this type of joint—$^1/_2$ inch.)

19. *Lap-Welded Joints Subject to Secondary Stress*

e.g. Horizontal joints of cylindrical tank shells, type *A* tanks,

These joints shall be welded on both sides with continuous fillet welds. They shall be designed to develop an efficiency of at least 50 per cent, based upon the thickness of the thinner plate joined. (This joint shall be at least equivalent to two-thirds that of a double full-fillet lap joint.)
(Maximum thickness permitted for this type of joint—$^5/_8$ inch.)

20. *Flat Tank Bottoms Resting Directly on Grade or Foundation—Type A Tanks*

Bottoms shall be built to one of two alternate methods of construction:

a. *Lap-welded construction*—Bottom plates need be welded on the top side only with continuous full-fillet welds on all seams.
Marginal sketch plates under the bottom ring of cylindrical shells, in the case of lap-welded construction, shall have the outer end of the joint "laid-up" and butt or lap welded to form a smooth bearing under the shell.
(Maximum thickness for lap welded bottoms shall be $^1/_2$ inch.)

b. *Butt-welded construction*—These joints shall be single welded from the top side, using suitable backing-up strip or equivalent means to insure complete penetration.

21. *Shell to Bottom Joint*

(Applies to vertical cylindrical shells with flat bottoms, type *A* tanks.)

The attachment between bottom edge of the lowest course shell plate and the bottom sketch plates shall be by a continuous fillet weld laid on both sides of the shell plate. The size of each weld shall be equal to the thickness of the sketch plate or the thickness of the shell plate, whichever is smaller, with a maximum size of $^1/_2$ inch. The sketch plate shall extend outside the tank shell a distance of at least 1 inch beyond the toe of the weld.

22. *Roof Plates*

a. Roofs not subject to hydrostatic pressure from tank contents, nor to vapor pressure greater than 3 inches of water: Such roof plates need be welded on the top side only with continuous full-fillet welds on all seams.

b. Roofs subject to hydrostatic pressure from tank contents, and/or to vapor pressure greater than 3 inches of water: Such roof plate joints shall be designed to conform to the efficiency values given in Paragraph 15.

23. *Unsymmetrical Butt Joints*

The wide faces of unsymmetrical V or U butt joints may be on the outside or the inside of the tank plating.

VI—WELDING DESIGN DETAILS

24. *Maximum Thickness of Material to Be Welded*

a. Maximum thickness permitted for lap-welded joints subject to primary stress from weight or pressure of tank contents—$^1/_2$ inch.
e.g. Vertical joints of cylindrical tank shells, type *A* tanks.
All joints below the point of support in suspended bottom, type *A* tanks.
All joints in low pressure type *B* tanks.

b. Maximum thickness permitted for lap-welded joints subject to secondary stress—$^5/_8$ inch.
e.g. Horizontal joints of cylindrical tank shells, type *A* tanks.

c. Maximum thickness for lap-welded flat tank bottoms resting directly on grade or foundation, type *A* tanks—$^1/_2$ inch.

d. Maximum thickness of metal permitted to be field welded—$1^1/_2$ inches.

25. *Minimum Laps for Lap-Welded Joints*

a. Joints subject to primary stress from weight or pressure of tank contents—5 *T*.
e.g. Vertical joints of cylindrical tank shells, type *A* tanks.
All joints below the point of support in suspended bottom, type *A* tanks.
All joints in low pressure, type *B* tanks.
(Does not apply to roofs of type *A* tanks subject to vapor pressure only.)

b. Joints subject to secondary stress—3 *T* with a minimum of 1 inch.
e.g. Horizontal joints of cylindrical tank shells, type *A* tanks.
Flat tank bottoms, and roofs subject to vapor pressure only, type *A* tanks.

Where: *T* is the thickness of material welded (use the thinner plate if of different thicknesses).

26. *Intermittent Welding*

a. The length of any segment of intermittent weld shall be not less than 4 times the weld size with a minimum of $1^1/_2$ inches.

b. Intermittent welding shall not be used on tank shell plating.

c. Intermittent butt welds shall not be used.

d. All seams of intermittent welding shall have continuous welds at each end for a distance of at least 6 inches.

e. When a seam of intermittent welding intersects a plate joint, continuous welds shall be applied for a distance of at least 6 inches on each side of the joint.

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27. *Minimum Size Fillet and Seal Welds*

a. Plates $^3/_{16}$ inch and less in thickness shall have full-fillet welds. Plates over $^3/_{16}$ inch thick shall have welds of a size not less than one-third the thickness of the thinner plate at the joint, with a minimum of $^3/_{16}$ inch.

b. Sealing, when desired, shall not be accomplished by running a bead of minimum dimension along the intervals between intermittent strength welds, but by applying a continuous weld, combining the functions of sealing and strength and changing section only gradually and as changes in the required strength may necessitate.

28. *Minimum Length of Welds*

a. The minimum length of any weld shall be four times the size, with a minimum of $1^1/_2$ inches, or else the size of the weld shall be considered not to exceed one-fourth its length.

b. The effective length of a fillet weld shall not include the length of tapered ends. A deduction of at least $^1/_4$ inch shall be made from the over-all length as an allowance for the tapered ends.

29. *Finish of Plate Edges*

a. The welding edges of plates may be universal mill edges or they may be prepared by shearing, machining, chipping or mechanically guided gas cutting, except that irregular edges may be prepared by manually guided gas cutting.

b. When edges of plates are gas cut, the resulting surface must be uniform and smooth and must be freed of slag accumulations before welding. All cutting shall follow closely the lines prescribed.

c. Shearing of material for butt-welded joints shall be limited to $^1/_2$ inch thickness or less. Material for all permitted thicknesses of lap-welded joints may be sheared.

30. *Joint Stagger*

Shell plate joints subject to stress from weight or pressure of tank contents shall have joints in adjacent courses staggered by at least one-fourth the distance between such joints.

VII—DETAILS OF WELDING PROCEDURE

31. *General*

All welds in the tank and structural attachments shall be made in a manner to insure complete fusion with the base metal, within the limits specified for each joint, and in strict accordance with the qualified procedure.

32. *Preparation of Welding Surfaces*

Surfaces to be welded shall be free from loose scale, slag, heavy rust, grease, paint and any other foreign material excepting tightly adherent mill scale. A light film of linseed oil or spatter film compound may be disregarded. Joint surfaces shall be smooth, uniform and free from fins, tears

and other defects which adversely affect proper welding. A fine film of rust adhering after wire brushing on cut or sheared edges that are to be welded, need not be removed.

33. *Weather Conditions*

Welding shall not be done when the temperature of the base metal is less than 0° F.; when surfaces are wet from rain, snow or ice; when rain or snow is falling on the surfaces to be welded; nor during periods of high wind, unless the operator and the work are properly protected. At temperatures between 32° and 0° F., the surface within 3 inches of the point where the weld is to be started, shall be heated to a temperature warm to the hand before the welding is started.

34. *Cleaning Between Passes*

Each pass of weld metal on multi-pass welding shall be cleaned of slag and other loose deposits before applying the next pass.

35. *Tack Welds*

Erection tack welds used in the assembly of joints subject to primary stress from weight or pressure of tank contents and those used for assembling the tank shell to bottoms are to be removed ahead of the continuous welding. Tack welds used in the assembly of joints subject to secondary stress, such as those in flat bottoms, roofs and circumferential seams of cylindrical tank shells of type *A* tanks, need not be removed providing the cover beads thoroughly fuse the added metal into the tack welds.

36. *Peening*

a. Peening of weld layers or passes may be used to prevent undue distortion. Surface layers shall not be peened.

b. Peening shall be performed with light blows from a power hammer using a blunt-nosed tool.

37. *Weld Contour*

a. In all welds, the surface passes shall merge smoothly into each other.

b. Undercutting of base metal in plate adjoining the weld is a defect and shall be repaired, except as noted in Paragraph 48*a*(3) and (4).

c. All craters shall be filled to the full cross section of the weld.

38. *Weld Reinforcement*

On butt joints, no part of the finished face in the area of fusion shall lie below the surface of the base plate adjoining. The weld reinforcement shall be a minimum, preferably not more than $^1/_{16}$ inch above the surface.

39. *Chipping and Gas Gouging of Welds*

The chipping at the root of welds and chipping of welds to remove defects may be performed with a round nosed tool, or by gas gouging.

40. *Flat Tank Bottoms—Type A Tanks*

The bottom plates, after being laid out and tacked, shall be joined by welding the joints in a sequence which the contractor has found to result in

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b. Segments cut with a cylindrical tool are called trepanned plugs.

the least distortion due to shrinkage of the welding, and to provide, as nearly as possible, a plane surface.

41. *Tank Shell*

a. On vertical joints, weld metal for any of the passes may be applied with either upward or downward progress of the welding, provided the contractor shall have qualified the direction he selects for each pass, in his procedure qualification and operator tests.

b. The shell plates shall be joined by welding the joints in a sequence which the contractor has found to result in the least distortion due to shrinkage of the welding and which will avoid kinks at the vertical joints.

42. *Matching Plates*

a. Lap joints: At all lap joints the plates shall be held in close contact during the welding operation. The separation shall be not more than $^1/_{16}$ inch. The size of the fillet weld shall be increased by the amount of the separation.

b. Butt Joints:

(1) In butt joints subject to primary stress from weight or pressure of tank contents, the adjoining plates shall be accurately aligned and retained in position during the welding operation, so that in the finished joint, the center lines of adjoining plate edges shall not have an offset from each other, at any point, in excess of 10 per cent of the plate thickness (use the thickness of the thinner plate if of different thicknesses) or $^1/_{16}$ inch, whichever is larger.

(2) In butt joints subject to secondary stress, the adjoining plates shall be accurately aligned and retained in position during the welding operation, so that in the finished joint, the thinner plate (if one is thinner than the other), or either plate (if both plates are of the same thickness), shall not project beyond its adjoining plate by more than 20 per cent of the plate thickness (use the thickness of the thinner plate if of different thicknesses), with a maximum of $^1/_8$ inch.

VIII—STIPULATIONS FOR TESTING WELDED SHELL JOINTS BY SECTIONING METHODS

43. *Application*

The examination of the welded structure by sectioning methods is more satisfactory when applied to butt joints, which makes it highly desirable that the shell of the all-welded tank be constructed with butt joints throughout. While it is possible to cut sections from lap-welded joints, it will require twice as many sections on the double-fillet-welded joints to obtain as many sections per unit length of joint as for butt joints.

44. *Sectional Specimens*

a. Sectional specimens are segments cut from the welded joints with a cylindrical cutting tool or spherical saw, which removes a portion of the plate bounding the welded joint and exposes thereon two cross sections of the weld. The segments must expose the full cross section of the welded joint.

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b. Segments cut with a cylindrical tool are called trepanned plugs. Segments cut with a spherical saw are called spherical segments.

45. *Number and Location of Test Segments*

a. Sectional testing shall be confined to tank shell joints, particularly those subject to primary stress from weight or pressure of tank contents. It need not be applied to flat tank bottoms resting directly on grade or foundation, nor to the welds between flat tank bottoms and the first ring of tank shell, nor to the welds connecting top curb angle to shell and to roof, for a roof not in contact with the stored liquid, nor to welds connecting manholes and other accessories.

b. *Joints subject to primary stress from weight or pressure of tank contents:* Cut one segment from the first ten feet of completed joint welded by each operator. Thereafter, cut one segment approximately every 100 ft. of joint. In cylindrical tank shells, type *A* tanks, cut at least one segment from the vertical seams of each shell ring. It is permissible to test two operators' work with one segment if they weld opposite sides of the same seam. When a segment of this type is rejected it must be determined whether one or both operators were at fault, by subsequent tests of the individual operator's work.

c. *Joints subject to secondary stress:* Cut one segment from approximately every 200 ft. of joint, with at least one segment from each circumferential joint of cylindrical tank shells, type *A* tanks.

d. It is to be recognized that the same welding operator may, or may not, weld both sides of the same joint. In so far as possible an equal number of segments shall be cut from the work of each operator welding on the tank, except this requirement shall not apply where the length of joint welded by an operator is very much less than average.

e. For lap-welded joints, two segments shall be removed at each test point, one from each fillet weld. They shall not be taken on the same center line, but shall be offset approximately three inches parallel to the axis of the joint.

f. Spherical segments shall be cut from the outside of the tank shell for butt-welded joints and from the welded surface for lap-welded joints.

g. The location for cutting the test segments may be determined by the purchaser's inspector.

h. Test segments shall be taken as the work progresses, as soon as practicable after all the joints accessible from one scaffold position have been welded.

46 *Size of Sectional Segments*

The width or diameter of the segment shall be not less than the width of the finished weld plus $^1/_8$ inch with a minimum of $^1/_2$ inch.

b. The segment shall be removed on the center of the weld in such a manner that at least $^1/_{16}$ inch of parent metal will be removed with the segment on each of the two sides.

47. *Preparation of Sectional Segments*

a. Sectional segments may be etched for inspection by any of the following methods:

(1) Without requiring any finishing or other preparation, place in boiling 50 per cent solution of muriatic (hydrochloric) acid until there is a clear definition of the structure of the weld. This will require approximately one-half hour.

(2) Grind and smooth segments with emery wheel and/or emery paper and then etch by treating with a solution of one part ammonium persulphate (solid) and nine parts of water by weight. The solution should be used at room temperature and should be applied by vigorously rubbing the surface to be etched with a piece of cotton kept saturated with the solution. The etching process should be continued until there is a clear definition of the structure of the weld.

(3) Grind and smooth segments with emery wheel and/or emery paper and then etch by treating with a solution of one part of powdered iodine (solid form), two parts of powdered potassium iodide, and ten parts of water, all by weight. The solution should be used at room temperature and should be brushed on the surface to be etched until there is a clear definition of the structure of the weld.

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b. To preserve the appearance of the etched segments they should, after etching, be washed in clear water, the excess water removed, then immersed in ethyl alcohol, and dried. The etched surfaces may then be preserved by coating with a thin, clear lacquer.

48. *Inspection of Sectional Segments*

a. The extent and character of weld defects revealed in the etched segments must not exceed the limitations given hereinafter for acceptable welds. Defects are defined as gas pockets, slag inclusions, lack of fusion, undercutting and cracks.

(1) For all welds, the etched surfaces of the segments shall show complete fusion between the weld metal and the base metal within the depth of the weld required for the applicable joint. There shall be no cracks in any weld. Defects in specimens, other than cracks or lack of fusion, shall be permissible:

(*a*) When there is slag inclusion between layers, substantially parallel with the plate surface and which is not more than one-half the width of the weld metal.

(*b*) When there is slag inclusion across the thickness of the plate not more than 10 per cent of the thickness of the thinner plate.

(*c*) When there are gas pockets that do not exceed $^1/_{16}$ inch in greatest dimension and when there are no more than six gas pockets of this maximum size per square inch of the weld metal or where the combined areas of a greater number of pockets do not exceed 0.02 sq. in. per sq. in. of weld metal.

(2) For butt and lap joints subject to primary stress from weight or pressure of tank contents, there shall be complete penetration and no undercutting.

(3) For butt joints subject to secondary stress, penetration is only required within the limits established by Paragraph 17. A maximum undercut of $^1/_{32}$ inch at each edge of the weld may be permitted, provided the unwelded gap plus the undercut shall not reduce the thickness of the joint more than $^1/_8$ of the thickness of the thinner plate joined.

(4) For lap joints subject to secondary stress, an undercut $^1/_{32}$ inch deep, measured along either leg, and lack of penetration at the root of $^1/_{16}$ inch, measured along either leg or the throat, shall be the maximum permitted, provided the size of the weld is increased to compensate for the deficiency in root penetration.

b. Where a defective segment is located, additional segments shall be cut from the same operator's work 2 feet on each side of the defective segment wherever the joint length will permit. If additional defective segments are found, then more segments shall be cut at intervals of 2 feet on the same operator's work until the limit of the defective welding has been definitely established; or the contractor may proceed to replace all the welding done by that operator without cutting out additional segments.

c. Defects in welds shall be removed by chipping or by gas gouging from one or both sides of the joint, as required, and rewelding. Only sufficient cutting out of defective joints is to be required as is necessary to correct the defects. Replacement welds in joints shall be checked by repeating the original test procedure.

49. *Method of Closing Openings from Which Segments Have Been Removed*

Subject to the stated limitations, openings may be closed by any of the following methods:

a. *Openings cut with a spherical saw:* For butt-welded joints place a backing-up plate on the inside of the tank shell over the opening. For lap-welded joints the parent plate opposite the weld will usually serve as a backing-up plate. Fill the opening completely with weld metal. Rebuild fillet welds where cut.

b. *Trepanned plug openings for joints subject to secondary stress only:* Insert a disk in the hole, which disk shall have a fairly close fit in the hole, and shall have a thickness at least $^1/_8$ inch less than the thickness of the thinner plate at the joint. The disk shall be inserted in a mid-position between the surfaces of the thinner plate for butt-welded joints and in a mid-position of the continuous plate for lap-welded joints. Both sides of the disk shall be welded over completely, fusing the circular edges of the disk into the plate material and making the surfaces of the weld substantially flush with the plate surfaces. Rebuild fillet welds where cut.

pockets of this maximum size per square inch of the weld

and making the surfaces of the weld substantially flush with the plate surfaces. Rebuild fillet welds where cut.

c. Trepanned plug openings for joints subject to primary or secondary stress and where the thickness of the thinner plate at the joint is not greater than 1/3 the diameter of the hole: Place a backing-up plate on the inside of the tank shell over the opening. Fill the hole completely with weld metal applied from the outside of the tank shell. Rebuild fillet welds where cut.

d. Trepanned plug openings for joints subject to primary or secondary stress and where the thickness of the thinner plate at the joint is not less than 1/3, nor greater than 2/3, the diameter of the hole: Fill the hole completely with weld metal applied from both sides of the tank shell. Rebuild fillet welds where cut.

e. Trepanned plug openings for butt joints subject to primary or secondary stress and where the thickness of the thinner plate at the joint does not exceed 7/8 inch: Chip a groove on one side of the plate each way along the seam from the hole. The groove at the opening shall have sufficient width to provide a taper to the bottom of the hole, and the length of the groove on each side of the opening is to have a slope of 1 to 3. Using a backing-up plate on the side opposite which the chipping is done, or a thin disk (not over 1/8 inch thick) at the bottom of the hole, fill the groove and the hole with weld metal.

f. Trepanned plug openings for butt joints subject to primary or secondary stress and for plates of any thickness: Chip a groove on both sides of the plate each way along the seam from the hole. The groove at the opening shall have sufficient width to provide a taper to the middle of the plate, and the length of the groove on each side of the opening is to have a slope of 1 to 3. Place a thin disk (not over 1/8 inch thick) in the hole at the middle of the plate and fill the grooves and the hole on both sides with weld metal.

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50. *Record of Segments*

a. The segments, after removal, shall be properly stamped or tagged for identification, and, after etching, kept in proper containers with a record of their place of removal as well as of the welding operator who performed the welding. A record shall be made by the inspector of all segments, with their identification marks, on a developed shell-plate diagram.

b. After the completion of the structure, the segments may be retained by the purchaser, if he so desires, otherwise they may be discarded.

IX—TANK TESTING

51. *Testing Flat Bottoms Resting on Foundations or Grades*

After the bottom has been completely welded, including the attachment of the first course shell sheet, oil or water, to be supplied by the purchaser, may be pumped underneath the bottom, maintaining a head of at least 6 inches of liquid, by holding that depth around the edge of the bottom, inside a temporary dam; or the joints may be tested with a suitable material such as strong soap solution or linseed oil under air pressure or vacuum; or the joints may be tested by the magnetic dust method. The bottom

shall be made entirely tight to the satisfaction of the purchaser's inspector.

52. *Testing Shell—Type A Tanks*

Upon completion, the entire tank shell shall be tested by filling with water. If the tank has a gas-tight roof, fill to the level of 2 inches above the capacity line. If sufficient water is not available to fill the tank, test may be made by painting all seams on the inside with a highly penetrating oil, such as automobile spring oil, or by applying air pressure in the tank as required for roof tests in Paragraph 53, or by both methods, carefully examining the outside of the seams for leakage; or the joints may be tested by the magnetic dust method. All leaks discovered by the above tests and indicating extensive porosity of the joint at any point, shall be repaired as described in Paragraphs 57 to 60 inclusive. Where water is not available, the final test may be made with the liquid to be stored, except that liquids giving off inflammable vapors at atmospheric temperatures shall not be used.

53. *Testing Roof—Type A Tanks*

If a tank has a gas-tight roof (such as oil storage tanks), when the tank shell is tested with water in accordance with the provisions of Paragraph 52, the roof may be tested by applying an internal air pressure equivalent to 1.5 times the opening pressure of the vent valve (except that the maximum allowable test pressure is three inches of water or 0.11 pound per square inch) and applying a suitable material such as strong soap solution or linseed oil to all seams; or the joints may be tested by the magnetic dust method. Isolated pinhole leaks may be caulked mechanically, but for any indication of considerable porosity in the seam, an additional bead of weld metal may be laid over the porous section, or the porous section may be removed and rewelded.

Where no water is available, and where a tank is tested with a liquid to be stored that may give off inflammable vapors under application of heat and/or where the tank is not entirely gas free, the only safe method by which vapor pressure can be developed for testing is by pressure as generated by the thermal expansion of the gases. Repairs either by caulking or welding should be deferred until the tank is entirely gas free.

54. *Testing Low Pressure Type B Tanks*

These tanks shall be tested in accord with the design requirements. They shall preferably be filled with water and then hydraulic or air pressure applied to the extent of the test requirements. Check all seams in contact with water for leaks, and check all seams in contact with air with a suitable material such as strong soap solution or linseed oil. The joints may be tested by the magnetic dust method.

55. *Hammer Testing*

Welded joints shall not be tested by hammering.

56. *Final Test*

Before acceptance, entire tank, when filled to its capacity level with the liquid to be stored, must be tight and free from leaks.

X—REPAIRS

57. *Repairs by Peening*

No leak in a weld shall be repaired by peening only, except that mechanical caulking will be permitted on pinhole leaks in roof seams not in contact with stored liquids, type *A* tanks.

58. *Tanks Under Liquid Load*

Repairs of defects discovered after tank is filled with water for test shall be made with water level at least two feet below the point being repaired, or with the tank empty, if repairs are on or near the tank bottom. No welding shall be done on any, except water tanks, unless all lines connecting thereto have been completely blanked off.

59. *Tanks Under Pressure*

No repairs shall be attempted on tanks under pressure, or while filled with any inflammable liquid or gas, in storage or for test. In such cases, it is recommended that the tank be emptied and washed out and/or steamed out, or otherwise gas-freed in a safe manner, and all lines connecting thereto blanked off, before any repairs are made.

60. *Tanks with Inflammable Contents*

After the repairs have been made, and where no water is available for final filling test, and the product (if other than water), to be stored in the tank must be used for the test, before refilling the tank, extra care in inspection of all the welded joints should be exercised, and all points of possible defects tested with penetrating oil and/or air pressure in tank, to a maximum of 3 inches of water or 0.11 pound per square inch. If, after these precautions, the tank shows leaks on being filled with any inflammable liquid or gas, no repairs shall be attempted by the manufacturer except in a manner approved in writing by purchaser's engineer and in the presence of purchaser's inspector.

PERSONNEL OF COMMITTEE ON
RULES FOR FIELD WELDING OF STORAGE TANKS

H. O. Hill, *Chairman*.....Bethlehem Steel Company
L. M. Dalcher, *Secretary*.....American Welding Society
H. C. Boardman.....Chicago Bridge & Iron Company
E. W. Fowler.....National Board of Fire Underwriters
J. O. Jackson.....Pittsburgh-Des Moines Steel Company
C. W. Obert, Sr.....Union Carbide & Carbon Research Labs.
Walter Samans.....Sun Oil Company
H. A. Sweet.....Associated Factory Mutual Fire Ins. Co.

A WELDING COURSE FOR Mechanical Engineering Students

By G. B. CARSON*

WELDING has become such an important method of fabrication in almost every mechanical goods industry that its omission in a mechanical engineering curriculum would be open to serious criticism.

To teach welding merely as a skill of manipulation would be grossly insufficient from the standpoint of the mechanical engineering student. It is unquestioned that operator skill must play an important part in the results obtained from any manual welding process, but beyond such skills the engineer must have a complete and thorough understanding of the processes and physical properties available to him in commercial practice. He must, in addition, understand the fundamentals of design and performance characteristics of the various types of arc, gas, electric resistance and atomic hydrogen welding equipments available as industrial tools.

With these facts in mind, the course at Case School of Applied Science was designed. The college makes no attempt to compete with the many excellent trade schools, and consequently does not propose to turn out qualified welding operators. It does try to turn out engineers thoroughly grounded in the fundamental theory and practice of welding.

* Assistant Professor of Industrial Engineering, Case School of Applied Science, Cleveland, O.

The course in Welding Technique is open to seniors and graduate students in Mechanical Engineering, although

Table 1—References for Supplementary Reading, Available in Library

1. The Welding Encyclopedia—9th Edition—Welding Engineer Publishing Company
2. Procedure Handbook of Arc Welding Design and Practice—Lincoln Electric Company
3. The Oxwelder's Handbook—Linde Air Products Company
4. Electric Arc Welding—Harcourt
5. Oxy-Acetylene Welding and Cutting—Harcourt
6. Oxy-Acetylene Welding and Cutting—Plumley
7. Arc Welding Handbook—Holslag
8. Arc Welding Manual and Operator's Training Course—Hobart Brothers Company
9. Alcoa Aluminum and Its Alloys—Aluminum Company of America
10. The Welding of Aluminum—Aluminum Company of America
11. Metallic Arc Welding—Harris (Longmans, Green & Co.)
12. Electric Arc and Oxy-acetylene Welding—Atkins & Walker (Pitman)
13. The Welding Engineer Magazine
14. American Welding Society Journal
15. Oxy-Acetylene Tips
16. Catalog Studies

Table 2—Welding Technique Lecture-Recitation Topic Outline All Assignments Inclusive

NOTE: This outline is designed for coverage under a system of scheduling where each class period is nominally one and one-half hours in length. Three periods (in addition to those shown below) during the term are used for examination, not considering the final examination, which is of three hours duration.

Period Number	General Subject	Specific Subject	"Welding Handbook" Page Numbers Assignment for Study
1	Gas welding	Gas Welding	120–137
2		Gas Cutting	280–304
3		Fuel Gases and Cutting Effects	304–326
4	Arc welding	Electric Arc Welding	3–6; 25–53
5		Arc Welding Equipment	Mimeographed supplement
6		Factors Influencing Welding	53–62
7		Automatic Arc Welding	90–104; 116–119
8		Welding Electrodes	78–89
9	Testing welds	Weld Testing	643–658
10		Non-destructive Tests	687–709
11	Resistance welding	Electric Resistance Welding	153–166
12		Spot Welding	167–184
13		Automatic Resistance Welding	201–219
14	"Other processes"	Thermit Welding	251–279
15		Atomic Hydrogen Welding	138–152
16	"Bronze welding"	Brazing and Soldering	335–348
17		Bronze Welding of Cast Iron	958–963
18	Alloy steels	Welding Low Alloys Steels	464–496
19		Welding Stainless Steels	525–543
20	Non-ferrous alloys	Welding Copper Alloys	555; 559–570; 589; 591
21		Welding Aluminum Alloys	598–612
22	Pressure vessels	Welding Pressure Vessels	845–859
23		Welding of Boilers	879–895
24	Aircraft welding	Aircraft Structures	1042–1064
25	Machine welding	Welded Machine Structures	964–976
26		Jigs and Fixtures for Welding	780–802
27	General	Review of Welding Design	7–22
28		General Review	.....

students from other engineering departments are not barred from taking it if it can be made to fit into their schedule.

Three hours per week are devoted to lecture-recitation, and three hours per week to laboratory practice, during one semester.

All of the major welding processes are covered in the class room, and thoroughly discussed from the standpoint of the best common current practice. An attempt is made to definitely catalog each welding process in the student's mind in so far as scope, adaptability and usual results obtained are concerned.

In the absence of a good book, written specifically as a text, the American Welding Society Handbook was found to be the best text material, and accordingly was adopted. A list of reference books, recommended to students for supplementary reading is shown in Table 1.

Table 2 shows the schedule of assignments and the course outline in use during the current year.

Table 3 shows a statistical breakdown of the total time spent on the various branches of welding, expressed as a percentage of the total lecture-recitation time. It should be noted that the general heading "Resistance Welding" includes several important processes to mechanical

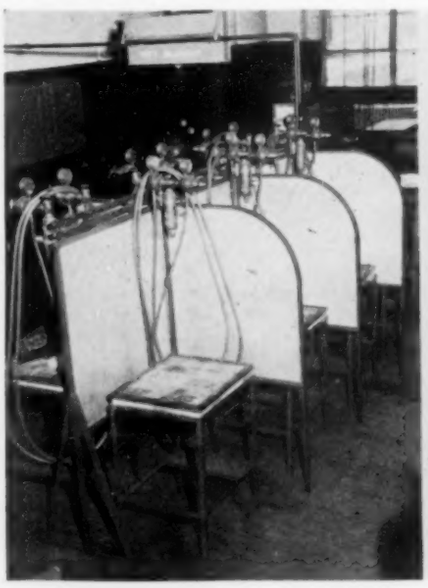


Fig. 1—General View of the Oxyacetylene Section of the Laboratory

Fig. 2—Close-Up of the Welding Station. Photos Taken by Ponstingl

Fig. 3—General View of Arc Welding Booths

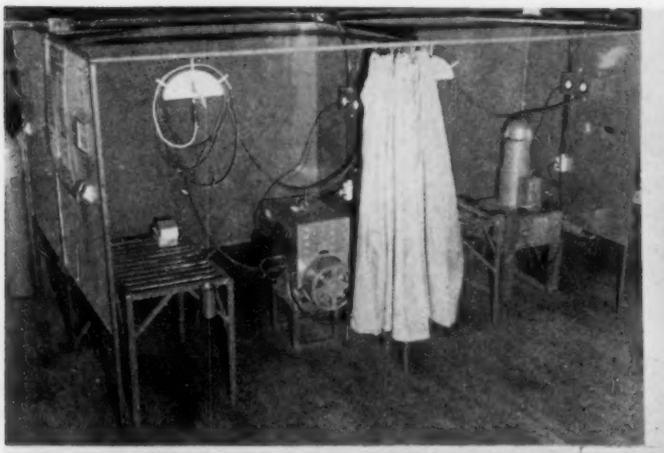


Fig. 4—Typical Instrument Installation

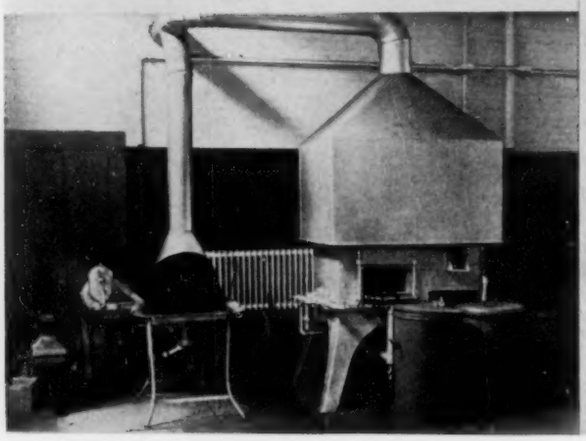


Fig. 5—Forge and Heat Treating Furnace

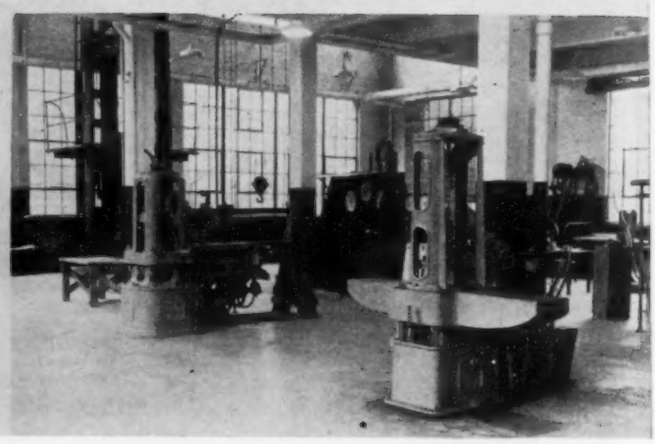


Fig. 6—Section of Materials Testing Laboratory

engineers, such as spot welding, shot welding, resistance butt welding, flash welding, projection welding, percussive welding, seam welding and their respective subdivisions.

The apparent absence of adequate coverage of design as applied to welding would doubtless provoke considerable justified criticism and comment, without the following explanation:

The Mechanical Engineering Department at Case School of Applied Science is divided into four major divisions (Design, Aeronautical, Heat-Power and Industrial). Welding Technique is taught in the Industrial Division, and this division cooperates closely with Professor R. R. Slaymaker's Design Division to prevent overlap, and promote course coordination. As the curriculum is now set up, the theory and practice of welding design is covered in the design courses given to all mechanical engineering students. The photoelastic stress analysis method is also fully covered in the design division. Consequently, any design covered in Welding Technique is by nature of review, and little time is devoted to it.

The laboratory time in connection with the course is at present divided into three major sections, although further procurement of equipment in the very near future will increase the number. The three divisions are (1) oxyacetylene welding and cutting, (2) arc welding processes and (3) field trips.

At the present time the laboratory uses the schedule outlined in Table 4, although it is emphasized that rapid progress in the industry results in frequent schedule revisions.

Reports are written on each major laboratory assignment, and emphasis is placed on analysis of results, in an attempt to create ability on the part of the student to "trouble shoot" causes of welding defects and point out remedies, since this is regarded as an important part of the mechanical engineer's duty.

The college departments of Metallurgical Engineering and Mechanics and Materials both have X-ray apparatus capable of radiographic analysis of welds. It is expected that fuller cooperation with these departments will be a natural development as the course is revised and im-

Table 3—Analysis of Time Devoted to Various Categories

Emphasis on processes	Arc welding Gas welding Electric resistance welding Bronze welding Other processes	53.58%
Emphasis on fabrication methods	Boilers Jigs and fixtures Pressure vessels Machinery	17.86%
Emphasis on testing	Destructive Non-destructive	7.14%
Emphasis on materials	Alloy steels Non-ferrous alloys	14.28%
Miscellaneous	General	7.14%
		100.00%

Table 4—Analysis of Welding Laboratory Time

1. Arc welding	1. Development of downhand technique	Practice	37.5%
	2. A study of weaving procedure	Practice	
	3. The effect of polarity on welding	Experimental	
	4. Welding generator characteristics	Experimental	
	5. Double and single vee butt joints	Practice	
	6. Fillet and vertical welding	Practice	
2. Gas welding	1. A study of gas welding apparatus, its care and operation	Practice	37.5%
	2. Autogenous gas welding	Practice	
	3. Gas welding, using filler metal (downhand)	Practice	
	4. Pipe welding, forehand and backhand technique	Practice	
	5. Vertical welding and gas cutting	Practice	
	6. Brazing, bronze-welding cast iron	Practice	
		Experimental	
3. Field trips	1. Copper brazing, atmosphere control furnaces		25.0%
	2. Radiographic testing of welds		
	3. Welding by mass production methods (automotive rear axle housing line)		
	4. Heavy machinery fabrication		

proved. Limited cooperative agreements already are in effect.

Weld testing is regarded as an important part of the work, and the use of testing apparatus is being increased with each course revision.

Figure 1 shows a general view of the oxyacetylene section of the laboratory.

Figure 2 is a close-up of the welding station. It should be noted that there is a fixed position for each piece of apparatus, designs of containers and brackets having been worked out by N. W. Popp, of the department Tool Room. It is felt that good care of apparatus is necessary to continued good results in welding, and that prepositioning the parts in specific locations definitely increases the productivity of each operator and lowers the cost.

Figure 3 shows a general view of typical arc welding booths, in which D.C. equipment of three distinct types of generator circuits are available, as well as high-frequency A.C. apparatus. Inspection windows are located in each booth so that the laboratory instructor may watch student work and offer corrective suggestions to him at frequent intervals.

Figure 4 illustrates a typical instrument installation, which may be supplemented with portable test meters when tests were run on welding generator characteristics. At other times, the student is able to check welding current and voltage as he sees fit. Instrument setting of welding circuit conditions has been found to aid materially in the instructional program.

Figure 5 is a general view of the forge and heat treating furnace, available for use in connection with welding experiments.

A section of the materials testing laboratory of the Mechanics and Materials Department is shown in Fig. 6. This laboratory has several modern machines, the largest having a capacity of 600,000 pounds.

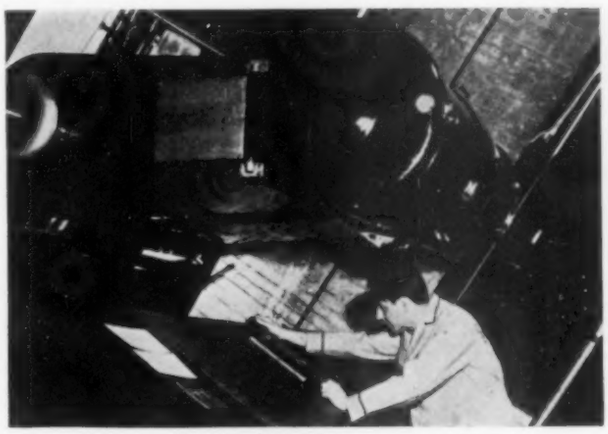


Fig. 7—X-Ray Laboratory

One machine of the X-ray laboratories of the Metallurgical Engineering Department is shown in Fig. 7. The maximum thickness of steel plate which can be explored is two inches.

It is not the intention of this paper to propose the system herein explained as the ultimate solution of an important instructional problem. On the contrary, it is intended to be a thought provoking discussion designed to provide welding engineers and industries with a knowledge of one of the present trends so that they in turn may offer helpful suggestions, and cooperate in an educational program of signal value to the advancement of engineering and technology.

DESIGN AND CONSTRUCTION of the World's Largest All-Welded Steel Lock Gate

By HERVEY E. BRAINARD and EDWARD J. RAMER*

INTRODUCTORY

THOUGH we are living in the so-called "automobile age," with the motor truck playing a most important rôle in commercial transportation, the movement of raw materials and commodities in bulk is still most economically served, where speed is not the dominant factor, by that ancient but reliable method of shipping via water.

The state possessing navigable rivers and lakes is endowed with a natural resource of primary importance, and, where such natural transportation routes are expanded and extended through the construction of canals and locks connecting these navigable bodies of water, the result is a communal and national asset of incalculable value.

New York State has been blessed, not alone with rivers and lakes, but also with many far-sighted citizens, who, as far back as 1792, pioneered in canal construction. The Barge Canal System of New York State, through the years, has not only been steadily improved to be able to meet the increasing demands made upon it, but has ever been alert to utilize any new processes or methods applicable to maintenance and operation.

* Designing Engineers, N. Y. State Dept. of Public Works, Albany, N. Y.

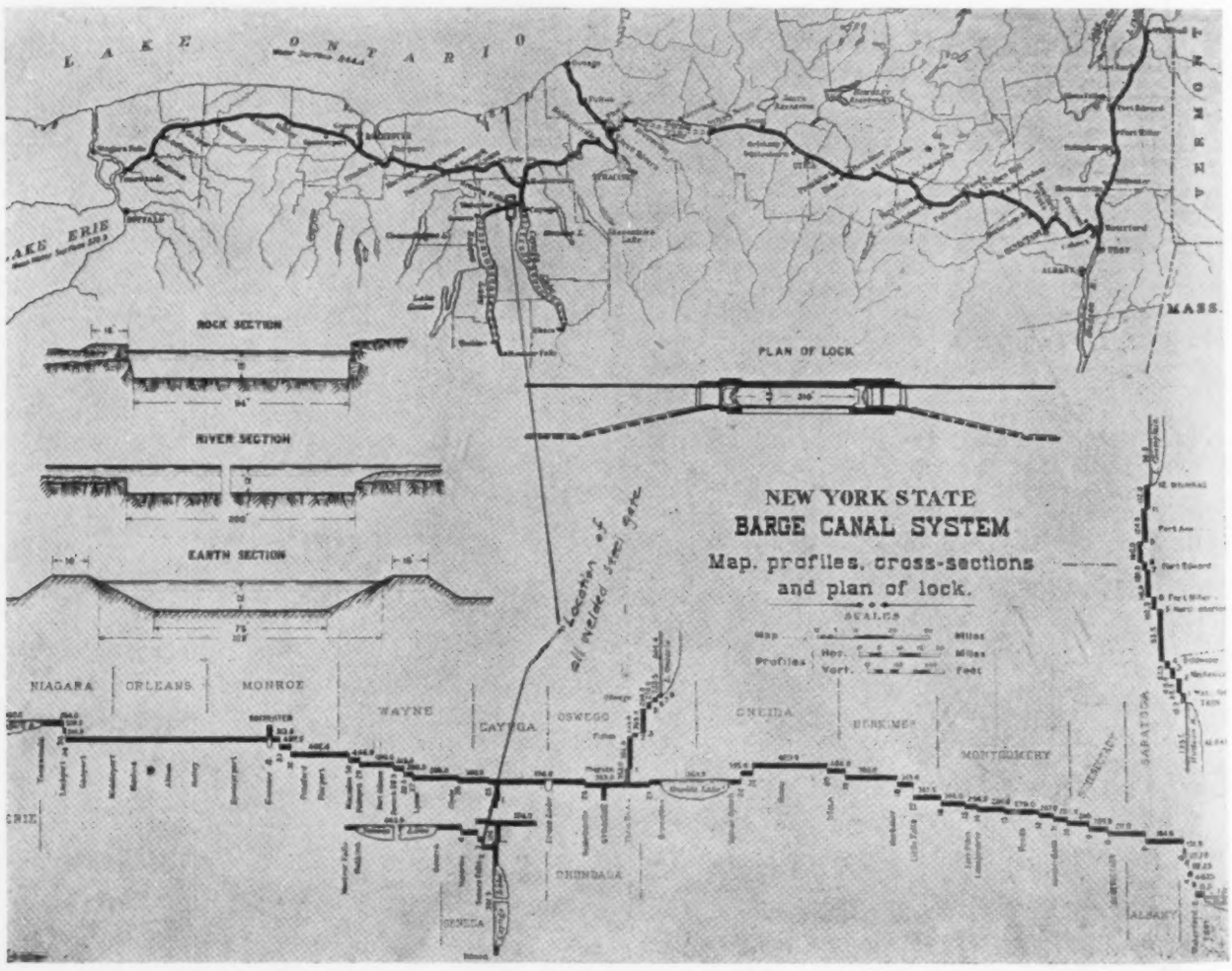


Fig. 1

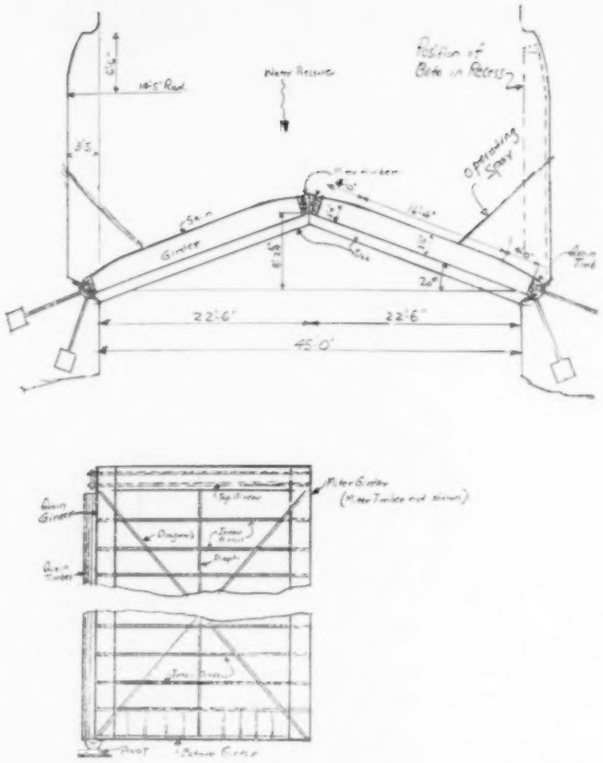


Fig. 2—Upper Sketch Shows Plan of Gate in Locks. Lower Portion—Elevation of Half of Gate

As early as 1918, arc welding was used in the Syracuse Shops of the Barge Canal System, when an arc welding unit was installed. Used at first for minor repairs and miscellaneous work, electric arc welding speedily proved its worth as a modern, efficient and even economical method of uniting the elementary parts that comprise steel structures of various types. In so far as repairs were concerned, where time is usually the most important factor, welding proved to be absolutely indispensable.

A transition from riveting to welding, perhaps not fully sensed at first, thus started. Now practically no riveting is used, and the welding equipment in the Syracuse Shops today, comprises two 6 lead welding machines, each rated 60 volts, 45 kilowatts, 750 amperes.

The maximum amperage in each lead is limited to 200 amperes but when 5 or 6 welders have occasion to be operating from one machine the amperage usually drops to an average of 180 amperes.

In addition to the above equipment, several portable gasoline driven welding generators are also used in shop and field varying from 200 ampere-25 volt capacity to 300 ampere-40 volt capacity.

During the past twenty years steel structures such as buoys, pipes, boilers, patrol launches, tugs, etc., which have been 100% welded, proved entirely satisfactory in all respects under exceptionally rough usage, and, when it became necessary to replace some old and damaged gates at various canal locks, it was but natural to turn to arc welding as the logical means to assure a safe, economical and watertight structure.

Cayuga Lake and Seneca Lake, the two largest of the famed "Finger Lakes," are navigable and are connected with each other by the Cayuga-Seneca Canal. This canal, in turn, is tied into the main line of the New York State Barge Canal System.

There is a difference of 63.5 feet in the elevations of these two lakes making it necessary for shipping to use three locks along the Cayuga-Seneca Canal. One of these locks is a double lock at Seneca Falls, as indicated on the map of the Barge Canal System (see Fig. 1).

In 1936, several timbers at the lower end of one half of the middle gate cracked and moved out of line, making it imperative that immediate repairs of a temporary nature be performed, pending the construction of a new steel gate. This was done with the use of timber planks and steel beams, properly bolted in place. Since this gate has to sustain 39 feet head of water pressure with no aid from any back pressure, these temporary repairs were duplicated on the other half of the gate. While the gates in the locks of the Cayuga-Seneca Canal are of timber, all the 53 other locks on the Barge Canal System have gates of riveted steel construction. However, the gate recesses in the lock walls, the quoin plates for taking the thrust of the gates, the anchor bars which hold the gates while not under pressure and the pivots on which the gates rest are of very similar construction for all gates, regardless of height or type of construction. For this reason, it was unnecessary to design new settings for the welded gates as they are lighter than the riveted gates and stresses in the gate anchorages are dependent on the weight of the gate per linear foot but except for the load on the pivot, are independent of the height of the gate.

The depth of the girders on the welded gates was kept the same as for the riveted gates, as this was found to be economical as well as for the fact that it was necessary to fit the new gates into the recesses provided for the old ones.

This article deals with the design and construction of a new steel gate for the location mentioned. While the over-all height of 41 feet 6 inches for this gate does not make it the largest lock-gate in the world, we believe it is the largest *all-welded* steel lock-gate in the world to date.

DESIGN FEATURES

General.—The design of a canal lock-gate may be designated as a specialty in the field of structural design. Hence, a few words of explanation regarding its salient features will not be out of place.

The sketches shown in Fig. 2 are line diagrams of the type of lock gate (exclusive of the vertical lift type) used throughout the New York State Barge Canal System.

Fundamentally this type of lock-gate consists of a watertight steel skin, reinforced by a system of horizontal and vertical girders, braced by diagonals and so supported on pivots that it may be opened or closed speedily, as occasion demands.

With the gate entirely open, the only stresses its members have to resist are those of dead weight. When the gate is moving toward its closed position it is subject to wind loads as well as dead load; and, in its closed position it must be prepared to sustain the additional stresses brought upon it by water pressure.

In its final closed position, the entire gate is assumed to act as a three hinged arch in resisting hydrostatic pressure.

Skin Plates.—The steel skin plate is standardized at $^3/_8$ inch thickness. The usual rolled plates are specified down to that depth where, due to hydrostatic pressure, a stress of 16,000 lb. per sq. in. is reached. Below this depth, which varies with the spacing of the horizontal girders, $^3/_8$-inch steel buckle plates are used.

Since these buckle plates are so placed that the convex side of the buckle is in tension, their resisting strength is very great and more than sufficient for any depth met with on the New York State Barge Canal System.

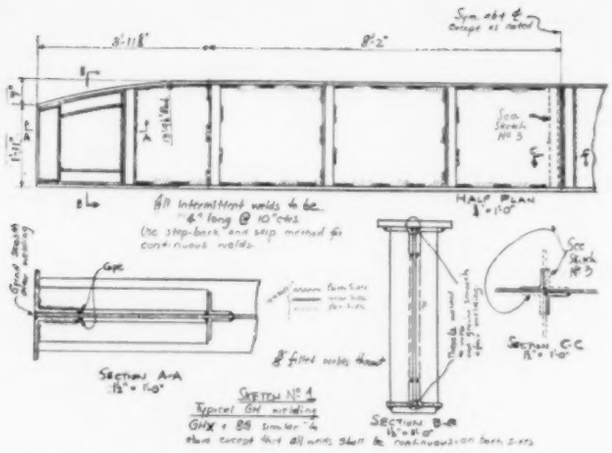


Fig. 3

Fastening the skin plates to the girders by means of arc welding assured a watertight job with no need for any caulking.

The fact that no sub-punched and reamed holes were needed, as would have been the case were the gates to be riveted, aided materially in keeping fabrication and assembly costs down, as well as entirely eliminating the usual expensive riveting necessary to assure a watertight structure.

Horizontal Girders.—Each horizontal girder had to be so designed as to be able to resist the longitudinal thrust brought upon it by the three hinged arch action of the gate, as well as the usual flexural stresses due to hydrostatic pressure which acts as a uniformly distributed load on the girder.

Direct and flexural loads, of course, vary with the depth of the water.

This case of combined stress made it necessary for more material to be placed on the compression flange than on the tension flange of the girder; and, the use of arc welding made it possible to secure a most efficient and economical distribution of metal.

Further economy was effected on the tension flanges, for by the use of welding, each and every square inch of metal was enabled to be effective in resisting stress. No allowance had to be made, as is customary in riveted design, for any loss of steel area due to holes being punched out for rivets.

In actual design, girders composed of web and flange plates of various standard sizes are investigated with particular reference as to how their resisting values compare with the distribution of metal assumed.

A careful study of several trial designs aided materially in arriving at a final decision as to the most effective and economical "make-up" of girders for any particular "h" or depth of water.

It is possible, due to the varying depths of the water, to use a different girder for each location of the girders in the complete gate.

However, since this gate was to be fabricated, assembled, welded and erected by the State forces, we standardized on two types of girders (designated as GH-heavy girder and GL-light girder) in order to keep the number of plate sizes down to a minimum as well as for other practical reasons.

Bottom Girders.—The bottom girder cannot be designed on exactly the same basis as was the usual horizontal girder, for the web plate of the bottom girder must be strong enough to safely resist, in flexure, the upward hydrostatic pressure resulting from the maximum depth of water possible at the lock. Also, the tension flange receives water pressure, in addition to the usual longitudinal thrust and bending coming on the girder as a whole.

No support is assumed from the sill, and by a rather involved and lengthy investigation of all possible stress-inducing factors, based on standard basic formulas covering tension, compression, flexure and combined stress, we derived three formulas, based on using a maximum bending stress of 16,000 lb. per sq. in.

Gate Frame and Diagonals.—In designing the gate frame, we used the same basic theory on which we had designed the original steel riveted gates, not only because this original method of reasoning was fundamentally sound, but also because our steel riveted gates had stood up so well through many years of severe usage.

The gate frame (actually frame of one leaf) is composed of four plate girders, namely, the miter girder, the quoin girder, the top girder and the bottom girder; as well as two diagonals connected to the ends of the girders by gusset plates, making the above girders a continuous beam system.

The diagonals are assumed to carry direct tension or direct compression only.

Refer to Fig. 2 for location of above members.

In so far as wind load stresses are concerned, the value of 20 lb. per square foot of exposed surface was used, and the total wind load was assumed as being uniformly distributed over the entire face (skin) of the gate.

From the construction of the gate, half of this total wind load transferred to and was uniformly distributed over the length of the miter girder. The other half transferred to and was uniformly distributed over the length of the quoin girder.

Based on this distribution, the reactions on the gate at the pivot support, at the anchorage at the top of gate, and at the operating spar were readily determined.

Since the diagonals could only take direct stress, and since the direct stress in any one diagonal had the same value at the two ends of that diagonal, it was possible to derive the shear and moment diagrams for the four girders of the frame, based on the principles of continuity.

Welding Design.—The welding design of this gate was based on the permissible unit stresses specified in the Standard Specifications for Arc Welding Metal Bridges as adopted by American Association of State Highway Officials in 1935.

These specifications may be considered rather conservative as compared with the usual welding specifications, but it must be borne in mind that this gate, in addition to having to resist varied and combined types of

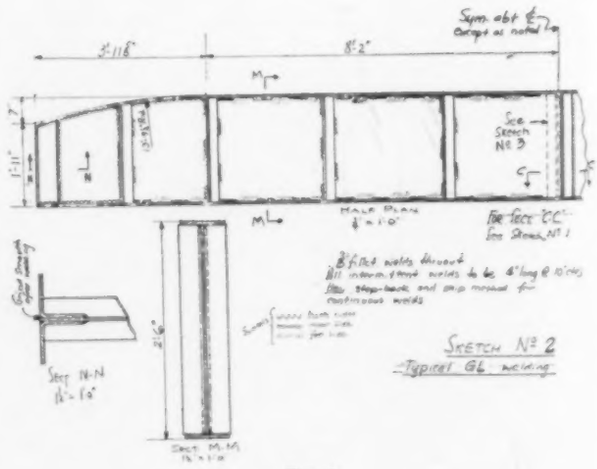
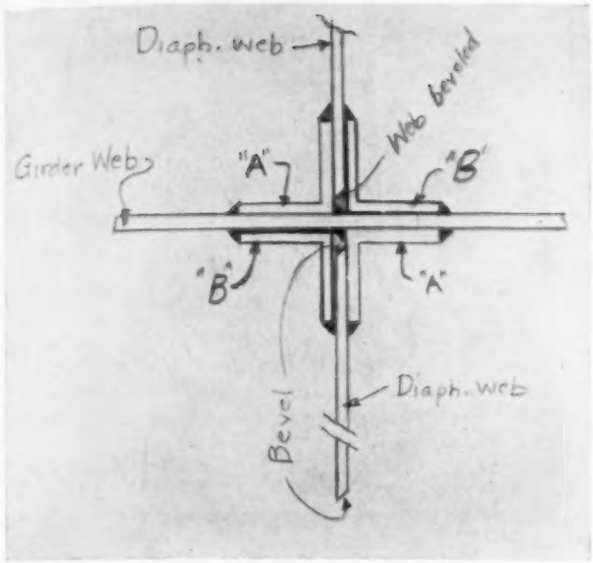
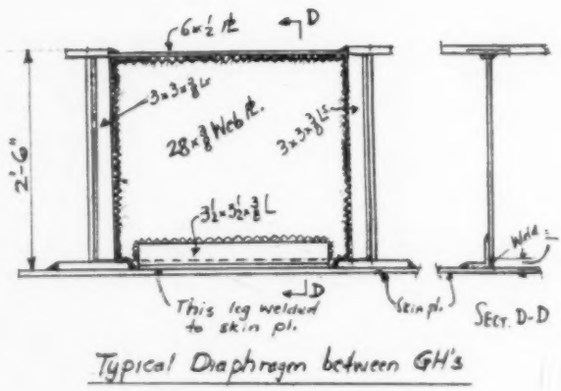


Fig. 4





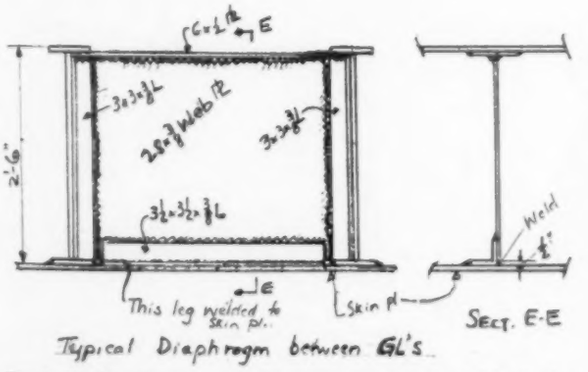


Fig. 5—Welding Sequence for Diaphragms. 1st Step Weld Angles. 2nd Step Weld Diaphragm Plates to Angles "A." 3rd Step Weld Angles "B" to Diaphragm Web and to Girder Web

stresses, also had to resist possible corrosion due to the water in the canal, and finally, bare or washed electrodes were used throughout.

The welding design was based on using $^3/_8$-inch fillet welds throughout, and in so far as was possible all work was so placed for welding that flat welds could be made.

In making continuous welds, the step-back and skip method (skipping about 4 inches) was specified in order to prevent any accumulation of stress or distortion.

The maximum length of any individual weld deposited at any one time was specified as 4 inches with sufficient time for cooling between welds so that no appreciable warping would occur.

Another reason for specifying 4-inch lengths was based on the fact that we found from our experience that one electrode would supply approximately 4 inches of weld material, and so sufficient cooling time was automatically made available by the operator in replacing electrodes, with no appreciable delay in welding progress.

Since it was essential that this structure be absolutely watertight, a truly economical distribution of weld material, based on stress-resisting requirements only, was not possible in most portions of the gate.

This, of course, meant the use of more continuous welding than would have been the case in the ordinary non-watertight structure of equivalent size.

However, it was possible to apply scientific analysis to ascertain the amount and location of welding required for the horizontal girders, exclusive of the bottom girder which had to be watertight.

The welding required to safely connect the flange or cover plates to the web plate of any girder is determined by the intensity of the horizontal shear brought into action by the maximum loads on the girder.

The amounts of horizontal shear vary along the length of a girder and are directly related to the values of the vertical shear at the same section of the girder.

The arrangement of the welding designed for this girder under maximum loads was used for all the other girders (except bottom girder) as no further economy could be effected without violating the requirements of the particular specifications we were using. This is similar to that requirement in specifications for riveted structures where certain maximum spacing of rivets must be adhered to.

It may be mentioned that while the welding sketches

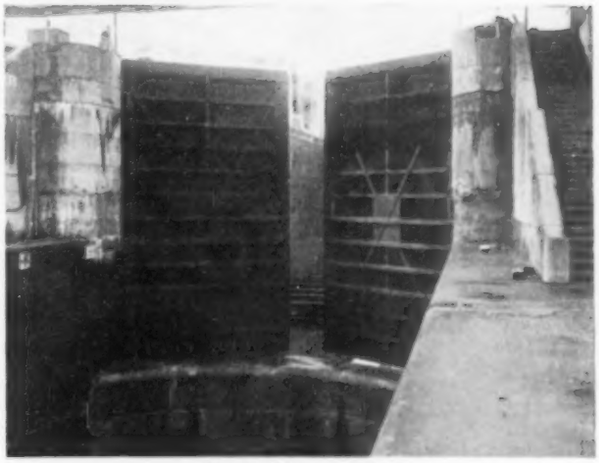


Fig. 6—Views of Gates

indicate the use of staggered intermittent welds, in actual production chain intermittent welds were used as recommended by AMERICAN WELDING SOCIETY.

CONCLUSION

Savings.—We do have figures as to the weight involved in this welded steel lock-gate as compared with the weight of a riveted steel lock-gate of equivalent strength. The weight of total steel necessary to construct one complete riveted steel lock-gate sufficiently strong to withstand these maximum stresses is 180,000 pounds, while the weight of total steel in our welded lock-gate is 154,000 pounds showing a saving of 15% for material alone in favor of the welded design.

Therefore, we feel we are conservative when we estimate that this all-welded lock-gate shows an immediate saving in actual cost of at least 10% over a riveted lock-gate of equal strength.

In addition to this saving in initial cost, operating costs will be somewhat lower because the 15% less dead weight to be moved each time it is necessary to open or close the lock-gate should be reflected in lower power costs.

This 15% saving in dead weight should also affect maintenance costs very favorably. The pivot supports, operating struts, etc., will, without a doubt, last much longer.

In fact, savings of welded design over riveted design are so apparent and the welded structure so satisfactory otherwise in more important aspects, that it may be mentioned herein that a duplicate of this gate is being fabricated right now in our Syracuse Shops for use at the lower end of this same double lock.

In addition, the writers are preparing designs and drawings for other all-welded gates of various sizes for the locks on the Cayuga-Seneca Canal to replace the present gates. Since more time is available for design, we hope to show about 20% saving in dead weight through eliminating as many shapes as possible, and concentrating on the use of plates which offer a more direct means of utilizing arc welding to its full value.

A study of the photographs will disclose the fact that welding also makes for beauty. This welded lock-gate, as compared with riveted gates, presents a truly, modern "stream-lined" appearance.

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Time-to-Rupture Tests of Welded Alloy Steel Pipe

By E. SIEBEL and K. WELLINGER

TO DETERMINE the behavior under load at elevated temperatures of steels for steam pipes, it is not sufficient merely to determine the rate of elongation at the end of two days. It is necessary at the very least to make time-to-rupture tests in which the time to cause specimens to rupture at a given temperature and stress is measured. Rate-of-elongation tests having shown that annealing of pipe welds reduced the rate of elongation, it was not surprising that annealing also increased the time for rupture at a given stress.

The specimens for the time-to-rupture tests were cut from arc welds in pipes ($8^5/_8$ inch o.d., 0.83–0.87 inch wall) made of steel containing 0.12 C, 0.8 Cr, 0.4 Mo, Fig. 1. The reinforcement of the weld extended 0.20 inch above the surface of the pipe. The specimens were 0.63 inch wide. Some were tested as-welded; others were heated 30 min. at 900–930° C., cooled in air, reheated to 650° C. for 30 min. and again cooled in air. The tests were made at 500° C. in an electric furnace 47 inches long, 3.2 inches i.d. Temperature was constant to within ±2° C. in the middle of the specimen.

The results, Fig. 2, show that annealing is beneficial in raising both strength and ductility. In short time tests, Table 1, in which fracture occurred in $^1/_2$ hour, fracture of as-welded specimens occurred outside the weld and heat-affected zone. Fracture of specimens stressed for 30 or 62.5 hours at 45,500 or 40,000 lb./in.², respectively, occurred through the middle of the weld, despite its 20% larger cross section compared with the pipe. The fractures were intergranular following the ferrite-pearlite structure of the weld metal. On the other hand, the annealed specimens at these stresses withstood 36 and 273 hours, respectively, fracture occurring in the heat-affected zone. An as-welded specimen that had been heated for some time at 650° C. underwent 4.6% elongation in 4 inches after 310 hours at 45,000 lb./in.² without fracture.

Extended abstract of "Festigkeitsverhalten von Rohrschweissungen bei Dauerbelastung," published in *Z. VDI*, **84** (4), 57–59 (1940) and *Arch. Eisenhüttenwes.*, **13** (9), 395–396 (1940). The authors are associated with the Technical College of Stuttgart, Germany.

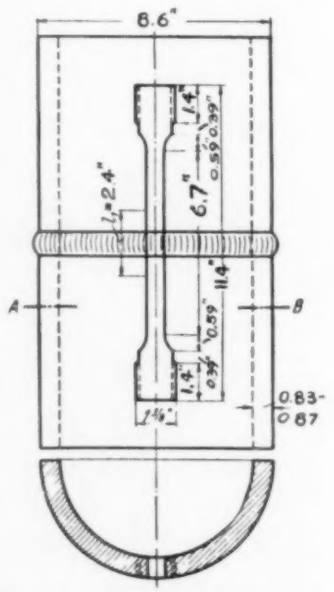


Fig. 1—Specimens Cut from Welded Pipe

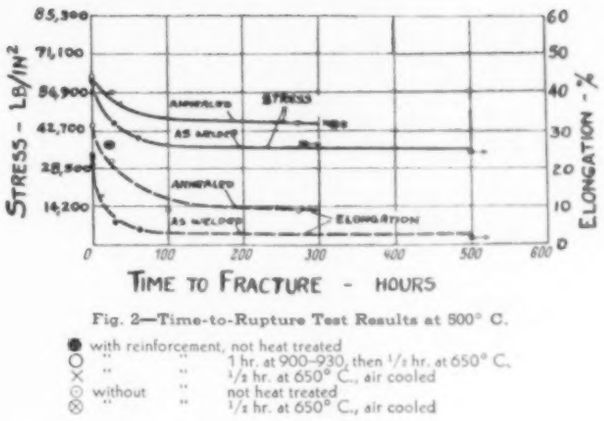


Fig. 2—Time-to-Rupture Test Results at 500° C.

● with reinforcement, not heat treated
○ " " 1 hr. at 900–930, then $^1/_2$ hr. at 650° C.
× " " $^1/_2$ hr. at 650° C., air cooled
⊙ without " not heat treated
⊗ " " $^1/_2$ hr. at 650° C., air cooled

Table 1—Results of Short Time Tensile Tests ($^1/_2$ Hour to Fracture) at 500° C.

	As-Welded	Heat Treated
Yield strength	29,900	About 25,500
Tensile strength	61,600	62,600
Elongation % in 4 inches	22.3	31.6

Some results are given in Fig. 2 for specimens that had been machined on both sides to remove reinforcement and undercut. Although as-welded, machined specimens failed in the weld with no ductility after 22.5–24 hours at 37,700 lb./in.², machined specimens that had been heated 1 hour at 650° C. and air cooled had not failed after 320 hours at 45,500 lb./in.² Obviously heat treatment at 650° C. improves the weld a great deal.

Hardness surveys, Table 2, revealed that the lower layers of deposited metal were softer than the upper layers, which had not been heated by so many subsequent beads. Heating at 650° C. reduced the hardness of the outer beads and heat-affected zone to some extent. Heating at 900–930° C. removed all hardness inequalities. The difference between as-welded and heat treated welds cannot, therefore, be due to differences in hardness. It appears that the weakness and lack of ductility of the as-welded specimens at 500° C. is favored by high internal stresses, which are relieved by heat treatment.

Table 2—Brinell Hardness* of Weld Cross Sections

	Not Heat Treated	Heated 1 Hr. at 900–930° C. Then $^1/_2$ Hr. at 650° C.	Heated 1 Hr. at 650° C.
Unwelded pipe	144–153	140–144	143–153
Heat-affected zone	166–180	143–144	161–170
Inner layers of weld metal	160–164	138–143	159–164
Outer layers of weld metal	205	137–144	191–195

* 2.5 mm. ball, 187.5 kg. load, 30 seconds.

Welding Society ACTIVITIES—Related Events

METAL CONGRESS

The 21st National Metal Congress, to be held in Cleveland October 21st to 25th, is showing every indication of being such an outstanding collection of papers as to mark an epoch in the technical sessions of the cooperating societies. The AMERICAN WELDING SOCIETY has 55 papers to present at its sessions, while the Institute of Metals and the Iron and Steel Divisions of the American Institute of Mining and Metallurgical Engineers and the Wire Association have planned extensive programs.

The American Society for Metals will have approximately 14 sessions besides the educational lectures in the late afternoon and early evening.

The National Metal Exposition is "going to town." It is at present the largest show that has ever been held in the long history of the Society. Over 235 exhibitors have reserved 90,000 square feet of exhibit space, and three extensions of the "space available" have been rendered necessary by the enormous demand for representation in this exposition.

It has been determined that the theme of this exposition will be "New Aids to Production." This is particularly appropriate at this time in the light of the tremendous activity in national defense and industrial expansion.

The exposition is to be held in the Cleveland Public Auditorium concurrently with the National Metal Congress the week of Oct. 21st.

Hotel Statler will be the headquarters for the American Society for Metals, Hotel Cleveland for the AMERICAN WELDING SOCIETY and the American Institute of Mining and Metallurgical Engineers, and Hotel Carter will be the headquarters for the Wire Association.

1940—1941 OFFICERS, AMERICAN WELDING SOCIETY

Since no nominations other than proposed by the Nominating Committee have been made by 25 qualified members, as prescribed by the By-Laws, the nomination ballots are treated as election ballots. Accordingly, the following have been elected to office for year to begin on the adjournment of the 1940 Annual Meeting. These officers will be declared elected at the Business Session of the Annual Meeting.

President, G. F. Jenks, Colonel, Ordinance Dept., U. S. Army, Washington, D. C.

First Vice-President, K. L. Hansen, Consulting Electrical Engineer, Harnischfeger Corp., Milwaukee, Wis.

Second Vice-President, David Arnott, American Bureau of Shipping, New York, N. Y.

District Vice-Presidents: New York and New England—P. J. Horgan, General Electric Co., Lynn, Mass. Middle Eastern—E. T. Scott, Cleveland School of Welding, Cleveland, Ohio. Middle Western—D. H. Corey, Detroit Edison Co., Detroit, Mich. Pacific Coast—L. W. Delhi, Western Pipe & Steel Co., San Francisco, Calif. Southern—O. T. Barnett, Black, Sivalls & Bryson, Inc., Oklahoma City, Okla.

Directors-at-Large: H. O. Hill, Bethlehem Steel Co., Bethlehem, Pa. J. H. Deppeler, Metal & Thermit Corp., New York, N. Y. E. L. Mathy, Victor Welding Equipment Co., San Francisco, Calif. A. G. Bissell, Bureau of Construction & Repair, Navy Dept., Washington, D. C.

EXTRACTS FROM LETTER RECEIVED BY SOCIETY

Department of Commerce

BUREAU OF FOREIGN AND DOMESTIC COMMERCE, WASHINGTON

To: Trade Magazines.
From: Bruce Berckmans, Assistant Director
Subject: National Defense Information Obtainable from Field Offices of the War and Navy Departments

Letters have been pouring into various government agencies in this city during recent weeks, asking for latest information on industrial mobilization.

Most of them are from manufacturing firms (or trade associations of such firms) that wish to assist the government in every way possible, such as immediately adapting factory facilities to national defense needs.

The War and Navy Departments state that current information of this type can best be secured from their *field offices,* rather than by writing to Washington or by sending representatives to this city. The Navy Department maintains 27 major field purchasing offices in 23 cities, while the War Department has 46 major field procurement offices in 22 cities:

15 for the Ordnance Dept.
10 " " Quartermaster Corps
6 " " Corps of Engineers
5 for the Chemical Warfare Service
4 " " Medical Dept.
3 " " Signal Corps
3 " " Air Corps

I am informed that the officials at these 73 field offices are kept in closest touch with not only present purchasing needs but also with all other industrial mobilization matters pertaining to their areas. The addresses of these field offices, as well as data on the general type of materials which were recently being purchased, or may soon be, by the War Department may be secured.

COVER PICTURE

Believe it or not the house shown on our front cover is all arc-welded steel. Not a nail or a stick of wood was used in its construction—no lath—no plaster—no masonry. Maybe it's a new trend in architectural construction.

This attractive "Florida Home in Ohio" was just completed by Mr. E. A. Hobart, president of Hobart Welders, Inc. An enclosed swimming pool and tennis court are in the rear. Ten rooms and four baths make up this attractive country home in Edgehill Village at Troy, Ohio.

Needless to say it's fire, earthquake, vermin and rat proof.

GET IN YOUR RECORD

The AMERICAN WELDING SOCIETY several months ago sent to each Section three types of record cards as follows:

1. Welding Fabricator and Job Shops.
2. Consulting Engineers.
3. Members Interested in Committee Activities.

A sample of the card dealing with Welding Fabricators and Job Shops is reproduced on the opposite page.

It is extremely important that every member falling within these classifications fill in these cards so that they may be on file in the office of the AMERICAN WELDING SOCIETY.

With the new defense program the Society will undoubtedly be called upon more and more to supply the names of welding fabricators and job shops, consulting engineers and people who are specialists in work on certain committees. You can obtain a card from your Section or by writing direct to the office of the AMERICAN WELDING SOCIETY.

AMERICAN WELDING SOCIETY

File Record of Welding Fabricators and Job Shops

1. Name of Establishment: .....

2. Address: Street and number .....

city and state .....

3. Name of Owner: .....

4. Welding Processes Used (place check in space indicated; use two checks to indicate a process in which you specialize):

☐ ☐ Arc, D.C.	☐ ☐ Thermit
☐ ☐ Arc, A.C.	☐ ☐ Atomic Hydrogen
☐ ☐ Gas	☐ ☐ Hand Cutting
☐ ☐ Resistance	☐ ☐ Machine Cutting

5. Types of Material Handled (place check in space indicated; use two checks to indicate a material in which you specialize):

☐ ☐ Low Carbon Steel	☐ ☐ Cast Steel
☐ ☐ High Carbon Steel	☐ ☐ Copper, Brasses and Bronzes
☐ ☐ Alloy Steel	☐ ☐ Aluminum and its Alloys
☐ ☐ Stainless Steel	☐ ☐ Nickel and its Alloys
☐ ☐ Cast Iron	☐ ☐ Hard Surfacing

(over)

6. Nature of Welding Jobs Handled (place check under the *one* column that describes the relative amount of each type of work performed):

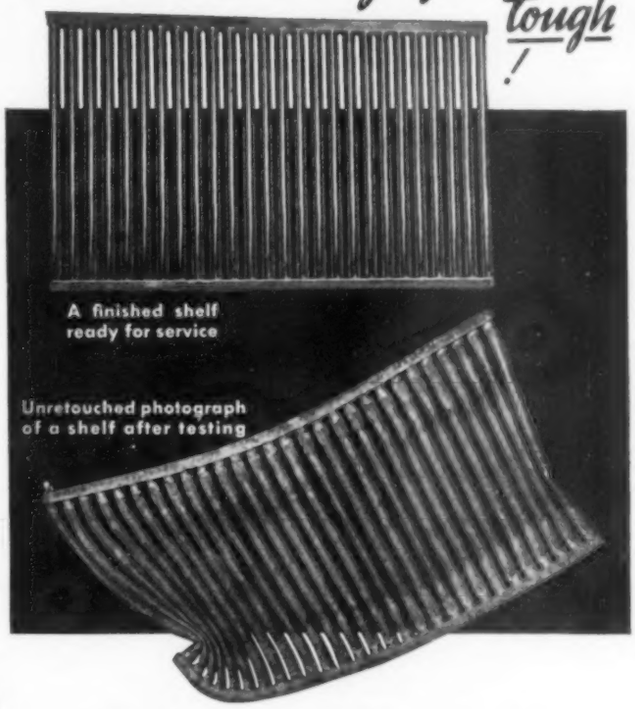
	Chief Work Performed	Perform Considerable Amount	Slight Amount	Very Little or none
(a) Repair				
(b) Construction of Miscellaneous Units in Small Lots				
(c) Large Quantity Repetitive Production				

7. List below whatever special equipment you have available (such as cranes, machine tools, jigs, annealing and heat treating furnaces, X-ray equipment, etc.)

8. Additional Remarks:

Date

More proof that SIL-FOS brazed joints are tough!



ALL the copper tubes in these water cooler shelves for refrigerators are joined to the headers with the low temperature alloy SIL-FOS. Before allowing the shelves to go into regular production, joints were given a severe test for leak-tightness, strength and ductility.

Just above is a shelf after being hydrostatically tested far beyond service requirements—and then crushed. Though tubes and headers were badly distorted, *every brazed joint remained sound and leak-tight.*

Braze a lap joint between two pieces of copper with SIL-FOS as instructed in Bulletin MP-16 (Copy on request). Test it as shown. You'll find the SIL-FOS joint as strong as the metal itself. For best results always use HANDY-FLUX with SIL-FOS.

This is typical of the reliable joints manufacturers all over the country are getting with SIL-FOS. But SIL-FOS does more than improve joint quality. It also speeds up production, reduces rejects to a minimum and lowers brazing costs. Try this effective money-saving alloy on your work. Write, today, for full details and BULLETIN WJ-58.

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Philadelphia, Pa.

IRON AND STEEL ENGINEERS

Plans have now been completed for the Annual Convention and Iron and Steel Exposition of the Association of Iron and Steel Engineers, which will be held in the Stevens Hotel, Chicago, Illinois, September 24, 25, 26 and 27, 1940. Owing to the tremendous demands heavy operations are placing upon it, the steel industry is faced with an immense rehabilitation problem. With a total annual capacity of 80,600,000 net tons, the industry over the past ten years has produced an average of 37,600,000 net tons per year. This means that much of the installed equipment has lain idle and suffered marked deterioration and obsolescence. In anticipation of the demands the steel industry will make upon the service industries, over one hundred manufacturers of steel mill equipment have reserved 85 per cent of the available space in the Iron and Steel Exposition, which is held in conjunction with the Annual Convention of the Association. In the Stevens Hotel, under one roof, all of the activities of the Convention and Exposition will be conducted. Thousands of the engineering and operating personnel of the steel industry will participate in the showing of the latest designs and developments in steel mill equipment and services.

The technical program has been closely supervised by prominent officials of the steel industry, with an eye to the future as well as the present-day demands.

FOLKS—MEET "CHIEF FLEETWELD"

Until the evening of May 22nd, he was just A. F. Davis, Vice-President and Secretary of The Lincoln Electric Company, Cleveland, Ohio, but that night at eight o'clock, he became "Chief Fleetweld" of the Osage Indian Tribe (see photo)!

It all happened during the International Petroleum Exposition at Tulsa, Oklahoma.

Having accepted an invitation to a meeting of the Fusion Welding Forum, Davis was listening attentively to the principal speaker whose opening remarks went something like this:

"Fellow members, we have with us this evening a man who is known far and wide in welding, having spent twenty-five years in the industry. He is a combination manufacturer, author, editor and advertising man. He knows probably more welders than any other man in the world and is loved and respected by all.

"It is a great honor for us that he is here tonight and it gives me great pleasure to present him a slight token of our esteem and of our appreciation for his unbounding enthusiasm for welding. Although his initials are 'A. F.,' every one calls him 'Charlie.'

"Mr. Davis, will you kindly step forward?"

Whereupon, Mr. Davis, taken entirely by surprise, walked to the platform to be presented with a tomahawk and a head

gear of the Osage Indian tribe, thereby being inducted into the Welding Forum.

In the presentation, Mr. Davis was ceremoniously named "Chief Fleetweld" and the tomahawk was referred to as "the first chipping hammer," the only difference between it and the modern chipping hammer being that the latter is used to chip welds instead of skulls.

National

Carbide

DEPENDABLE

EFFICIENT

ECONOMICAL

FOR WELDING and CUTTING

Use National Carbide in the Red Drum

Lincoln Building — NATIONAL CARBIDE CORPORATION — New York, N. Y.

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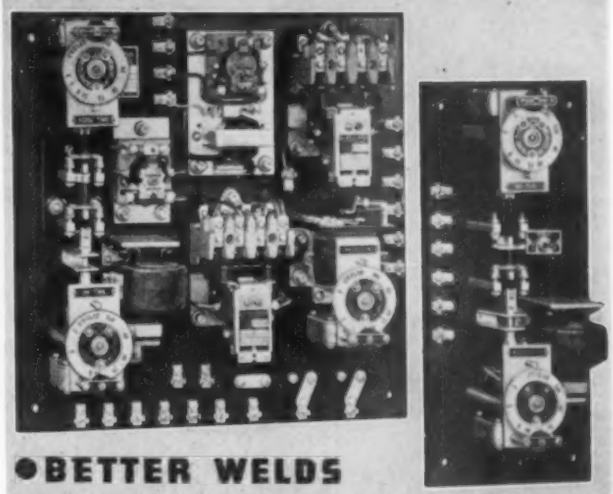
Automatic Control

OF INTERRUPTED SPOT WELDING WITH

SQUARE D

CONTROLLED INTERVAL TIMERS



● BETTER WELDS
● LONGER ELECTRODE LIFE
● INCREASED MACHINE CAPACITY

Interrupted spot welding consists of breaking the flow of current at controlled intervals while the electrodes remain clamped to the work. The process has advantages in the fabrication of thick cross sections, unusual shapes and hot rolled materials because—

1. Alternate heating and cooling intervals raise the metal to fusion temperature without overheating and annealing the electrodes. Reduces maintenance cost.
2. Brittle welds are avoided and the effect of scale or rust on the material surfaces is minimized. Better product.
3. Welding machine capacity for thicker materials is increased by applying several smaller current impulses in place of a single one of high value. Smaller machine investment.

The new Square D timer panels for air-operated welding machines can be equipped to automatically control the Heat and Cool periods of interrupted spot welding as well as the Squeeze, Hold and Off periods of the welding cycle. Pneumatic time delay mechanisms and high speed relays are interconnected in a circuit arrangement which eliminates sensitive adjustment and provides independent control of all functions. Similar timers are available for foot-operated and motor-driven machines.

Square D timers and welder panels are not costly and are easy to operate. *Write for Bulletin 38-017.*

SQUARE D COMPANY

DETROIT - MILWAUKEE - LOS ANGELES

IN CANADA: SQUARE D COMPANY CANADA LIMITED, TORONTO, ONTARIO

REPAIRING DREDGE

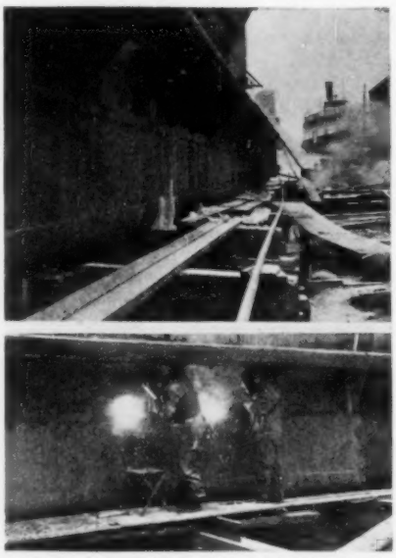
A large sand and gravel company was saved the purchase price of a new dredge in the reconditioning of hull plates which had been badly corroded by the action of sea air and salt water.

The water-line plates of this 141-foot long dredge, after many years of service, had been eaten away so badly that it had to be removed from service due to the serious leaking which developed. Extensive repairs to its hull or the purchase of a new dredge was necessary.

It was decided to attempt the replacement of the corroded plates by use of arc welding. The old plates all around the hull were removed and new sections were welded in their place. The supporting triangle sections for the side runways were cut from the old plates and suspended by temporary braces. The old plates were then cut out, and the new ones, each about 10 feet long by 27 inches wide were welded in place. A butt weld reinforced with a 3 x $^{5}/_{16}$-inch strap was used to join the bottom of the new section to the top of the old. At the top the new plates were welded to the steel deck plates.

The use of welding instead of riveting which was the method used in the original dredge construction was well justified by the results. The job was done much quicker and cheaper. Further, had rivets been used considerable additional weight would have been added to the dredge. It is estimated that 2800 feet of welds were made, and that close to 1600 pounds of $^{5}/_{32}$- and $^{3}/_{16}$-inch welding rods were consumed. The dredge now is in operation again, and the company has been relieved of the necessity to buy a new dredging unit.

This Close-Up of the Dredge Shows the New Plates Welded in Position. Note the Welded Reinforcing Strap Running the Length of the Hull; Its Purpose Is to Reinforce the Butt-Welded Joint at the Junction of the Old and the New Plates



Photos courtesy Westinghouse Elec. & Mfg. Co.

Two Welders at Work Replacing the Corroded Plates of a Sand and Gravel Dredge with New Steel Plates

F. L. PLUMMER

Fred L. Plummer, chief design engineer on Main Avenue Bridge, Cleveland, chosen by *Engineering News-Record* as the outstanding bridge of 1939, has been retained by a United States corporation as consultant in a soil slip problem threatening a South American plant. On his return to this country he will take residence, July 20th, in Warren, Pa., as chief research engineer for Hammond Iron Works of New York City and Warren, a position newly created by H. D. Kopf, president.

Prior to three years with County Engineer John O. McWilliams and County Bridge Engineer W. E. Blaser, Plummer, while associated with the late Wilbur J. Watson, was in charge of structural design of the Zeppelin dock, Akron, the Lorain-Central bridge, Cleveland, and the new high level bridge, Lorain, Ohio. He assisted Cleveland city engineers in designing Fulton Road bridge. He was consultant for the U. S. Engineers Corps office—handling flood control projects in Zanesville, Ohio, Huntington, W. Va., and Pittsburgh districts.

Plummer has taught structural engineering and allied subjects at Case School of Applied Science for fifteen years, and at Cleveland School of Architecture and John Huntington Polytechnic Institute for twelve and eight years, respectively.

His membership in engineering, technical and honorary societies includes AMERICAN WELDING SOCIETY, American Society of Civil Engineers, American

☆ Better and More Uniform Spot Welds
☆ Less "Down" Time
☆ Lower Dressing Costs

with the New

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MALLORY Tip Dresser

This new tool re-machines both upper and lower tips to their correct profile "on the job"... without necessitating removal of the tips from their water-cooled holders.

This not only saves valuable "down" time, but insures the use of uniform contact area with the work at all times. The result is better and more uniform welds... lower dressing costs.

The first Mallory Tip Dresser you try will tell you why they have been received so enthusiastically by the welding industry. Write today for prices and specifications.

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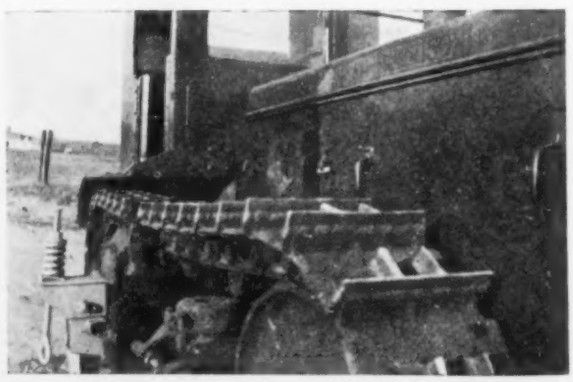
11 to 13½% Manganese Nickel Steel

SPECIAL SHAPE APPLICATOR BARS

For

RESTORING WORN DOWN TRACTOR TREAD GROUSERS



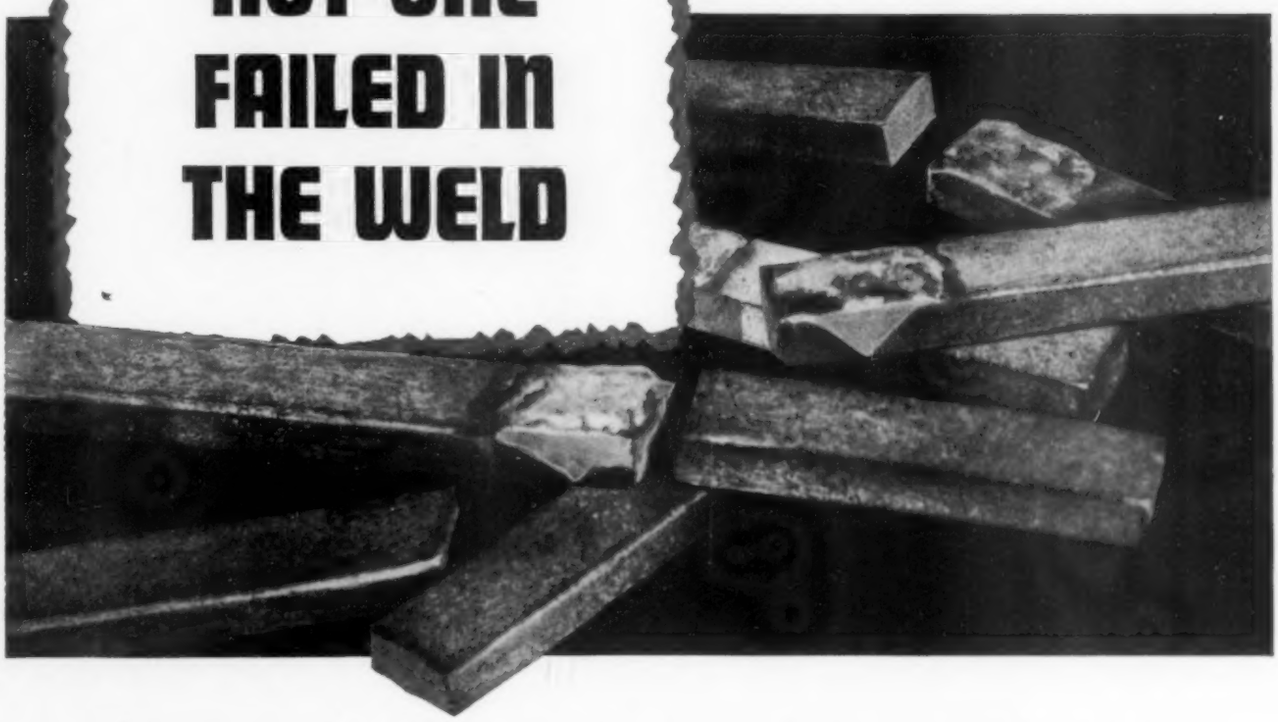
ATTACH WITH MANGANAL WELDING ELECTRODES

STULZ-SICKLES CO. Sole Producers 91 N. J. Railroad Ave. NEWARK, N. J.

Sold Thru Distributors Only

All failed in the parent metal

NOT ONE FAILED IN THE WELD



Laboratory inspected cast-iron bars were cut in two, the edges beveled, then welded together with Tobin Bronze... and subjected to straight pull strength tests. All failed in the cast iron... there were no failures in the Bronze! Tobin Bronze* is uniformly dependable—welders like the way it flows, and the tough, strong, durable bonds it produces.

The uniformity of Tobin Bronze is the result of expert metallurgy, close inspection and accurate laboratory control. That's why you can always count on Tobin Bronze.

There are 18 Anaconda Welding Rods ...each suitable for a special purpose. Their characteristics as well as welding procedures are outlined in detail in Anaconda Publication B-13. A copy will be mailed to you — without cost — for the asking.

• • •

Visit the Copper & Brass Industry Exhibit in the Hall of Industry, New York World's Fair, 1940

©N. Y. W. F.

*Reg. U. S. Pat. Off.

ANACONDA
from mine to consumer

Anaconda Welding Rods

THE AMERICAN BRASS COMPANY, General Offices: Waterbury, Connecticut

In Canada: Anaconda American Brass Ltd., New Toronto, Ont. • Subsidiary of Anaconda Copper Mining Company

Society for Testing Materials, American Concrete Institute, Society for Promotion of Engineering Education, Phi Beta Kappa in arts, Tau Beta Pi in engineering and Sigma Xi in science. He is past president of Cleveland Engineering Society, and is now in his third term as chairman of the AMERICAN WELDING SOCIETY's Cleveland section.

In Warren, Plummer will aid Hammond engineers in developing new types of low pressure and special shape storage vessels required by the petroleum and other industries.

AMERICAN AVIATION DIRECTORY

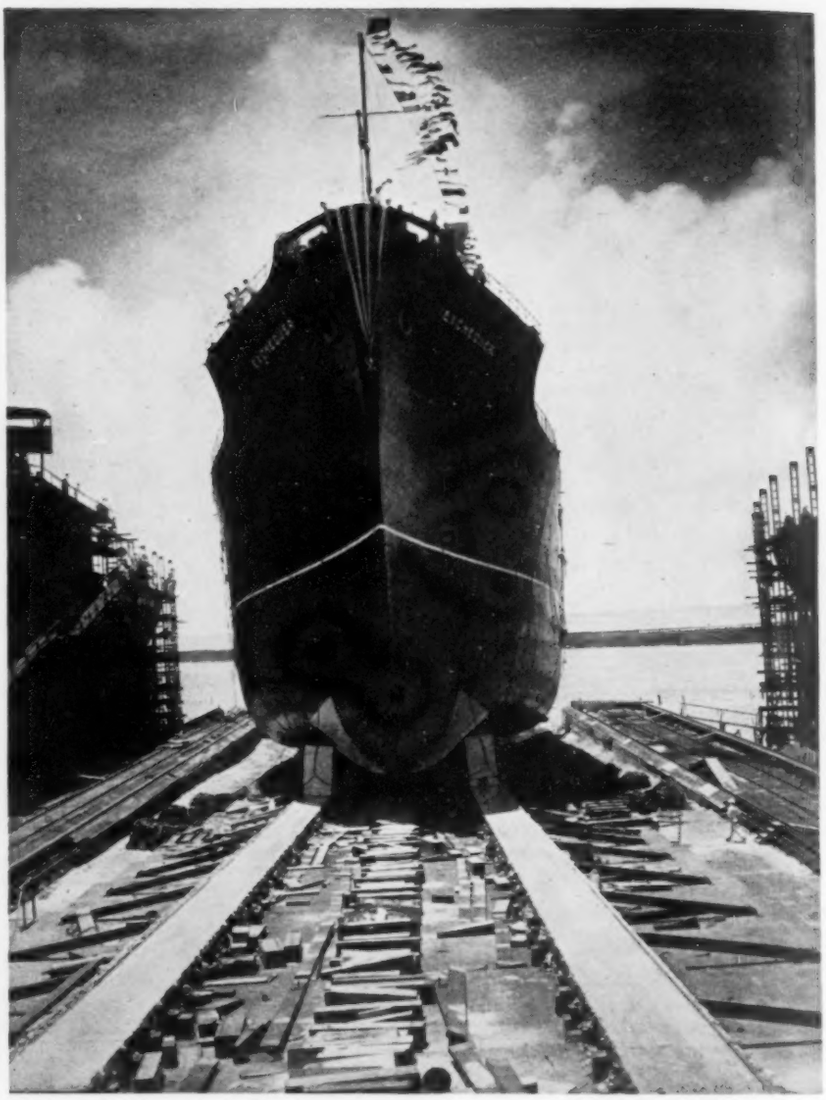
A very excellent directory of American Aviation including officials and companies in United States and Canada, has been issued by the American Aviation Associates, Inc., Earle Building, Washington, D. C. This is the first volume. It will be issued twice a year. Subscription price $3.00 per single copy; $5.00 per year.

A compact, comprehensive, accurate and useful directory of aeronautical industries and organizations in the United States and Canada has long been needed. At the suggestion of numerous executives in the air transport and aircraft manufacturing industries, the publishers have undertaken the task of launching a periodical directory as a service to those within the industry and to those outside the industry who have need of this information.

NATIONAL CYLINDER GAS COMPANY TO SUPERINTEND REGO DISTRIBUTION IN THREE STATES

The Bastian-Blessing Company has extended a RegO distribution franchise to the National Cylinder Gas Company in the states of Michigan, Ohio and Indiana, effective August 1st, according to E. L. Mills, Vice-President of the Bastian-Blessing Company.

Annual Meeting American Welding Society, Hotel Cleveland October 20-25, 1940



Launching the S.S. EXCHEQUER

The photograph shows the all-welded EXCHEQUER sliding down the launching ways in the yards of the Ingalls Shipbuilding Corporation at Pascagoula, Mississippi, on June 8th.

The S. S. EXCHEQUER is the largest vessel of its kind 100% welded ever built in the U. S. Its length is 492 feet, breadth 69 feet 6 inches, draft 28 feet 6 inches, H. P. 9350, speed 17 knots, displacement 17,600 tons. The vessel is of the shelter type construction with raked stem and cruiser stern. It was built for the American Export Lines, and will be put in service between New York and Calcutta, India.

REGO
WELDING AND CUTTING EQUIPMENT
- Welding Torches
- Cutting Torches
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- Regulators
- Outfits

FOR PLUS PROFIT SPECIFY REGO
Send for Catalog R-120 — with it you will have all the specifications you need for the buying of highest quality welding and cutting equipment.
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Buy "Proven Fluxes" with Years of Guaranteed Satisfaction behind them
The Trade-Name is "ANTI-BORAX"
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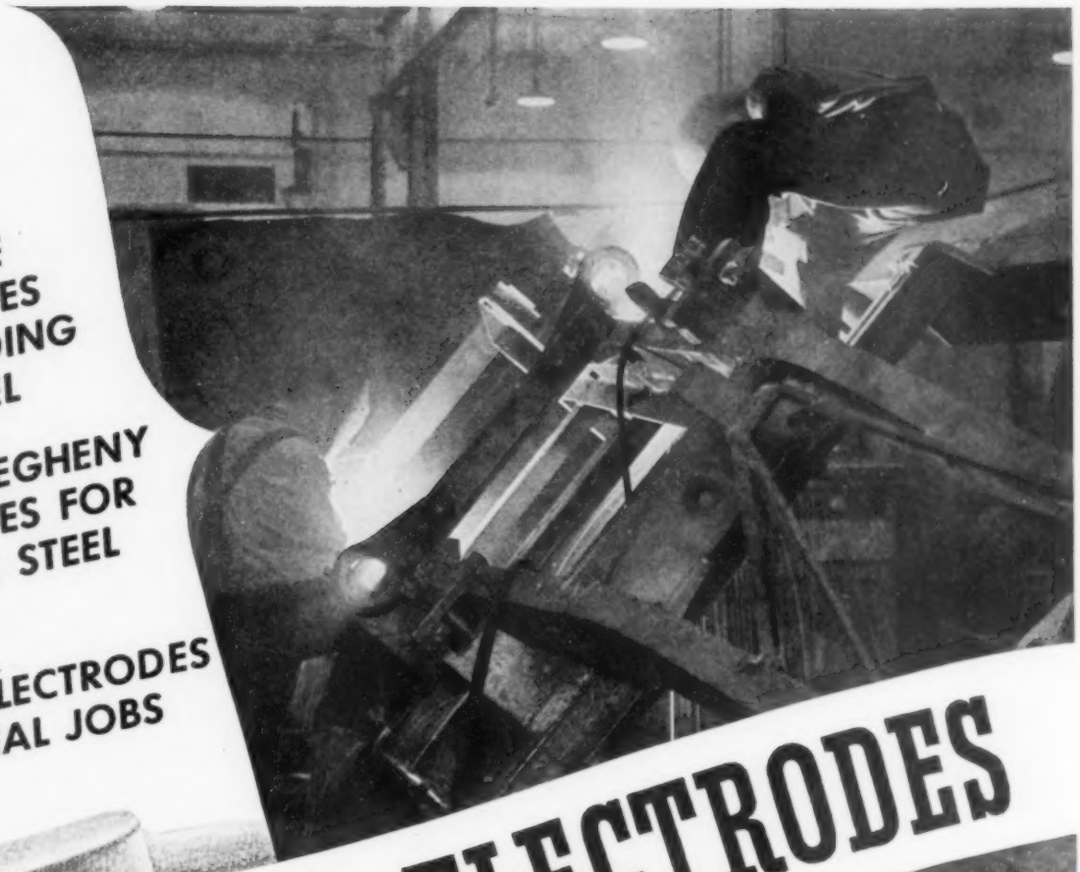
A Flux for every metal: Cast Iron Welding Flux No. 1.; Brazing Flux No. 2; Braz-Cast Flux No. 4, for bronze-welding cast iron; "ABC" Aluminum Flux No. 8 for sheet Aluminum and all alloys of Aluminum; Stainless Steel Flux No. 9; Silver Solder Brazing Flux No. 10; "Anti-Borax" Tinning Compound No. 11.
Send for Free Samples
ANTI-BORAX COMPOUND COMPANY
Fort Wayne, Indiana



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PAGE-ALLEGHENY ELECTRODES FOR STAINLESS STEEL WELDING

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SPECIAL ELECTRODES FOR SPECIAL JOBS

PAGE ELECTRODES

FOR BETTER WELDS!

● Every Page electrode is made to help you make better welds. The sole purpose of our broad program of research and experiment is to develop better products with which you can do better and more profitable work. • Out of this program have come electrodes that, on actual test, have proved themselves head and shoulders above any electrodes against which they were tested. • So, whatever welding job you have to do, give Page a trial. The results may surprise you.

BUY ACCO QUALITY *in Page Welding Electrodes; Page Wire Fence; Lay-Set Preformed Wire Rope; Reading-Pratt & Cady Valves; Campbell Abrasive Cutting Machines; American Chains; Ford Chain Blocks, Cranes and Trolleys.*

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•

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AIRPLANE-WELDING ACTIVITY

One of the busiest branches of the Technical Training Centre of the Royal Canadian Air Force, where 900 students are being taught the many trades linked with the maintenance of aircraft, is the oxyacetylene welding department. The light, easy-to-handle blowpipe shown here was especially designed for aircraft welding.

Photo courtesy Linde Air Products Co.

This welding method in which the base metal is melted by an oxyacetylene flame and fused with metal added from a welding rod is extensively used in the original construction of airplanes. Repair of broken parts by the same method effectively returns them to their original strength or better.

OBITUARY

Harold P. Peabody

Harold P. Peabody, well known Lynnfield Centre resident and chairman of the Lynnfield School Committee for the past eight years, died June 29th, at his home at 633 Main St., Lynnfield Centre, at the age of 62 years, 6 months and 20 days.

He began his business career in the employ of A. J. Wilkinson, hardware dealers, Boston, and for the past 32 years had been with the John A. Roebling and Sons' Company of Trenton, N. J., at the Boston office.

Mr. Peabody was an active member of the Society having joined in 1924. He was one of the organizers of the Boston Section. He served as Secretary of the Section from 1926–1927 and was Chairman from 1930–1931. For a time he served as a member of the Board of Directors of the Society and represented the Boston Section on the Board from 1932–1935. He continued his active interest in the affairs of the Section up to a recent date.

He is survived by his wife, three daughters, the Misses Elizabeth, Millicent and Martha Peabody, and one son, Robert; by a sister, Miss Harriet Peabody of Everett, and a brother, Robert C. Peabody of El Segundo.

R. O. Sossong

The Air Reduction Company announces with deepest regret the passing away of Raymond A. Sossong on Friday, June 28th, at his home in Larchmont, N. Y. Mr. Sossong was Assistant Vice-President and Manager of Gas Plants of the Air Reduction Company, with which he had been connected since 1917.

Mr. Sossong was a graduate of the Carnegie Institute of Technology, class of 1909, and was associated with the Searchlight Company before his affiliation with Airco. He was a Past-President and Director of the International Acetylene Association (1925–1926) and was a member of the Compressed Gas Manufacturers Association, the Uptown Club and the Oriente Beach Club.

Mr. Sossong is survived by his wife, Mrs. Wilhelmina Levermann Sossong; a daughter, June; a brother, Andrew C.; and three sisters, Mrs. Elizabeth Ende, Miss Minnie Sossong and Mrs. Frank Mayer.

AN OUTLINE OF METALLURGICAL PRACTICE

By Carle R. Hayward*

The present volume is not intended to replace any work which has yet appeared but is designed to occupy a new field where it will satisfy two demands. First it is to meet the desire of many engineers for a quick reference book which will give modern practice in extracting and refining most of the metals and will give general information regarding the sources, uses and important alloys of the metals. Second it is to assist students who are starting their metallurgical studies with no practical experience and little or no knowledge of the subject or its literature. Such a student is bewildered when faced by an array of processes, some obsolete, some active and some merely proposed but not yet commercial. This initial bewilderment prevents an immediate grasp of the subject which is necessary for the best results in teaching.

This book is just off the press. Published by D. Van Nostrand Co., Inc., 250 Fourth Avenue, New York. Price $7.50. 690 pages.

WELDED REINFORCEMENT FOR BRIDGE ROADWAY

Maine's vacation land has another tourist convenience to offer in the new suspension bridge from the mainland to Deer Isle in Penobscot Bay, replacing the less speedy ferry service of former years.

Photo courtesy Wilson Welder and Metals Co., Inc.

Welding of the steel reinforcing bars for the concrete roadway was done by Lewiston Welding Co., Lewiston, Me. The illustration shows the welding work in progress.

FOOTE MINERAL ADDS TO STAFF

Mr. William A. Maxwell, who has just received his degree in Chemical Engineering at the South Dakota School of Mines, has joined the research staff of the Foote Mineral Company, of Philadelphia.

Mr. Maxwell, who has specialized in the chemistry of the less familiar group of elements as well as mineralogy, will devote most of his time to process development.

HANDY AND HARMAN NEW YORK OFFICES AND PLANT ENLARGED

Extensive additions and alterations at the New York offices and plant of Handy & Harman, 82 Fulton St., to more efficiently take care of an expanding gold and silver business, are nearing completion. Added floor space of more than 4000 square feet has been occupied at their present location.

In recent years a large number of manufacturers of refrigerators, automobiles, airplanes, electrical appliances and metal products of all kinds, have become users of silver and particularly silver brazing alloys. There has also been an increase in the use of silver for electrical contacts and for corrosion resistance in containers and equipment for the chemical and food industries.

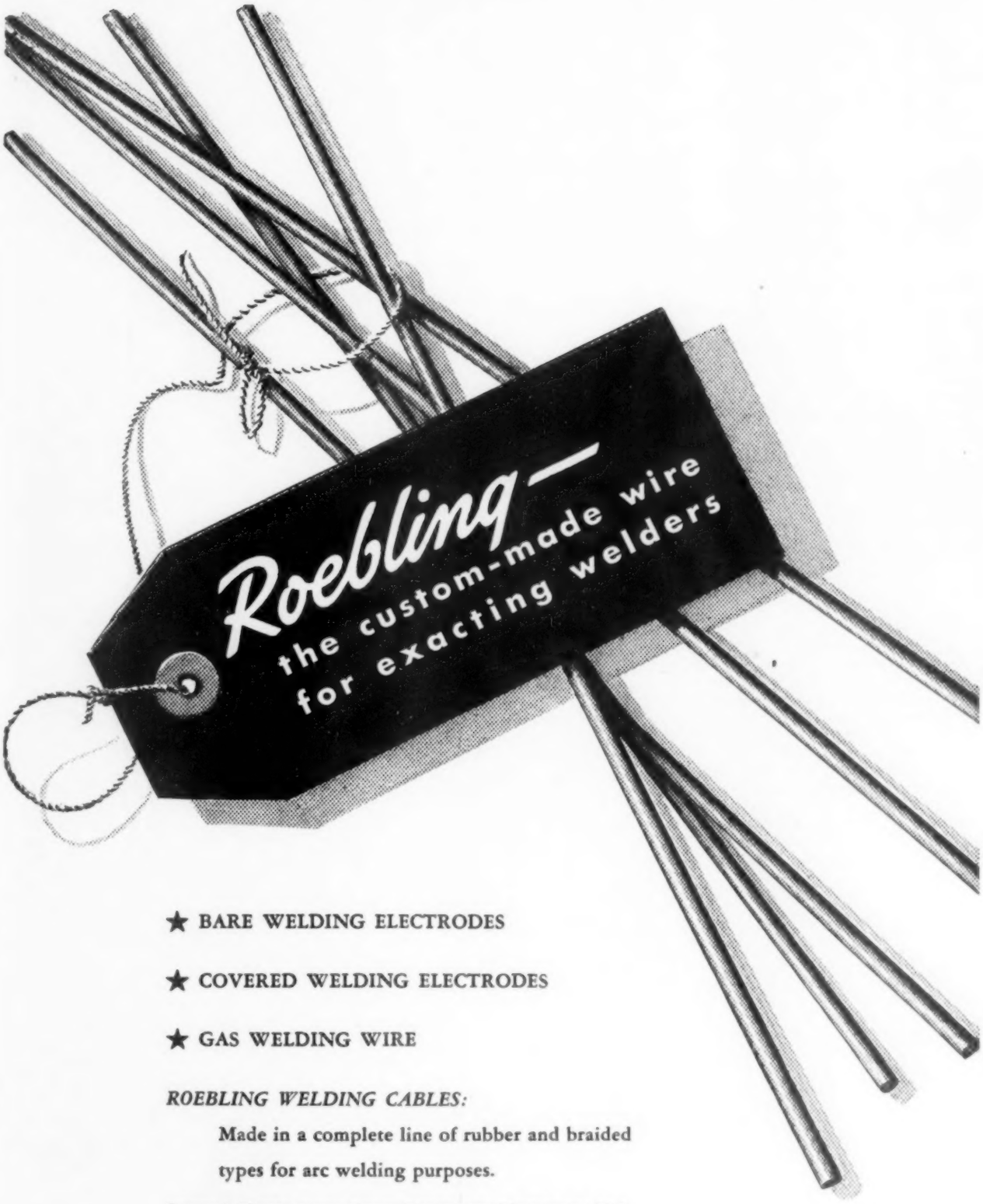
WELDING DIE CASTINGS

The procedure for welding die castings described by R. H. Ogden, Aladdin Rod & Flux Mfg. Company, Grand Rapids, Michigan in the June issue of THE WELDING JOURNAL, Supplement, page 230-s, is covered by U. S. Patent 2,055,360, according to Mr. Ogden.

OXWELD ELECTION

C. K. Bryce has been elected Vice-President of Oxweld Acetylene Company, a unit of Union Carbide and Carbon Corporation, New York. Mr. Bryce was formerly Manager of Factories.

* Professor of Process Metallurgy Massachusetts Institute of Technology.



★ BARE WELDING ELECTRODES

★ COVERED WELDING ELECTRODES

★ GAS WELDING WIRE

ROEBLING WELDING CABLES:

Made in a complete line of rubber and braided types for arc welding purposes.

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ONLY A FINE PRODUCT MAY JAR BEAR THE NAME ROEBLING

COMMUNICATION TO THE EDITOR

[Editorial Note: The Society is not responsible for any statement made or opinion expressed in its publications.]

June 19, 1940

Editor,
Welding Journal
33 West 39th Street
New York City

Dear Sir:

That article you published recently, by Mr. J. F. Lincoln, in which he described the simplicity of the arc welding process, has created considerable discussion. There is nothing I would like better than to see the sale of arc welding equipment double or triple year after year. I feel, however, that Mr. Lincoln has gone just a bit too far in minimizing the importance of trained operators.

He is undoubtedly referring to large plants that have used welding for a long time and have highly developed procedure control when he says, "The only thing that a welding operator can do is to hold the end of an electrode at a certain distance above the deposited metal and advance it along the seam to be welded at a certain speed. There is nothing more than that involved in this operation. It is neither complicated nor difficult. As a matter of fact, with proper electrode, proper setting of the welding machine and proper preparation of the work, it is practically impossible to make a weld which will not stand up in service, without having it so evident to the inspector that he will immediately reject it."

It seems to me that airplane manufacturers might just as logically advertise that, "The only thing that a pilot can do is to move the stick, push the rudder bar and give the engine the gun. There is nothing more than that involved in this operation. It is neither complicated nor difficult. As a matter of fact, with proper gasoline, proper manipulation of the controls, and fair weather, it is practically impossible to arrive at the wrong destination without having it so evident that the pilot can return to his starting point and try again."

Responsible for distribution of a well known line of arc welding equipment, I've been traveling about 30,000 miles annually for several years throughout the United States, Canada and Mexico, in order to get first hand information. Naturally, that has brought me into personal contact with large and small users of arc welding in various industries and I do not believe a large percentage of them would be any more interested in trusting their welding to inexperienced or untrained operators than in starting a flight across an ocean with an untrained pilot. (They're not always as successful as Corrigan.)

True, there have been remarkable developments and improvements during recent years with respect to equipment, methods and materials involved in arc welding. The process has unquestionably been greatly simplified but I do not believe this condition should be exaggerated—that anyone should be induced to adopt the process believing that it can be effectively and economically used by inexperienced or untrained personnel. Such a policy could hardly be expected to contribute to the well being of the industry as a whole, even if it were acceptable in certain exceptional cases.

Contact with large users and with AMERICAN WELDING SOCIETY sections has given me the impression that there is more and more attention being paid to qualification of operators as well as of methods and materials. Welding schools all over the country are now crowded with men learning to weld. Vocational schools are showing more and more interest in teaching arc welding. That would not be true if those men did not sense an immediate or future demand for trained operators. In fact, many of us can remember the time when lack of proficient operators was one of the important elements of sales resistance encountered by manufacturers of welding equipment.

It seems to me that it would be better for all concerned to admit that best results from arc welding call for its use by skilled operators who know something more about what they are doing and trying to accomplish than the mere mechanical manipulation of the welding arc. In the textbook used at our factory-operated, non-profit welding school we say:

"Anyone with average intelligence, a steady hand, and a real desire to perfect himself in the art can readily learn to weld with the electric arc. To become an expert operator, however, requires something more than mere ability to manipulate the welding arc." That statement, of course, is directly opposed to the one quoted in your editorial.

Continuing the quotation from this textbook: "The man who has had previous training and experience in some mechanical trade will develop more quickly into a proficient welding operator than the man without such training or experience. An experienced gas welder will find it extremely easy to become proficient with the arc due to his knowledge of metals, welding heats, etc."

In other words, while admitting the desirability of using trained operators, we try to point out the fact that it is not difficult to develop them, if none are available to the employer planning to adopt arc welding. Even where procedure control is so far advanced that little is left to the discretion of the welding operator, I personally believe that better welding may be expected when the operator knows "what it is all about."

Sincerely yours,
W. J. CHAFFEE, *Welder Division*
The Hobart Brothers Company

MILBURN SECRETARY

W. Leslie Lawrence was recently elected secretary of the Alexander Milburn Company.

Mr. Lawrence filled various positions with the company, first as Baltimore representative, then on National Sales, and a short time ago became one of the company's directors. He is well acquainted in the oxyacetylene field.

Mr. Lawrence succeeds Mr. Harvey H. Johnson, who passed away on June 2nd after serving the company for 25 years.

AIRCO ANNOUNCES RETIREMENT OF WILLIAM W. BARNES

The Air Reduction Company has just announced the retirement of William W. Barnes, Manager at Philadelphia. Mr. Barnes, who has won the admiration and respect of the entire oxyacetylene industry as a result of his keen insight and pleasant personality, has been active in the industry for 30 years.

William A. Barnes

William W. Barnes first became associated with the oxyacetylene industry in 1910 when he joined the Davis-Bournonville Company as Philadelphia Sales Manager. He held that position until 1922, when Davis-Bournonville merged with Air Reduction. As a result of the merger, Mr. Barnes became Airco's Manager at Philadelphia—a position he has held until his retirement.

LINDE OFFICERS

The Linde Air Products Company, a unit of Union Carbide and Carbon Corporation, New York, has announced the election of T. D. Cartledge and L. A. Bliss as Vice-Presidents, and of E. J. Hayden as Vice-President, Central Division.

Mr. Cartledge has been General Sales Manager and Mr. Bliss, Works Manager of the company. Mr. Hayden has been Manager of the Company's Central Division.

E. B. Suydam, formerly Assistant General Sales Manager, has been appointed General Sales Manager to succeed Mr. Cartledge; and P. B. Pew, formerly Assistant Works Manager, has been appointed Works Manager to succeed Mr. Bliss.

FIFTEEN YEARS PROGRESS BY RESISTANCE WELDING

WELDING COST REDUCED 66%

ON OIL DRUMS

From 1925 to 1940 resistance welding has made this tremendous saving over former welding methods in the steel barrel industry.

Fifteen years ago one highly skilled welder produced 20 oil drums per hour. Today, a resistance welding machine produces 200 drums per hour. Figured in direct labor cost, this amounts to a saving of 66%. Included in today's welding is a flash trimming operation, producing a cleaner weld, with no free scale inside the finished drum.

Since resistance welding has made these same savings in various industries, replacing more expensive methods, perhaps it can do the same for you. Any of the member companies listed here will be glad to consult with you on your particular problem.

RESISTANCE WELDER

MANUFACTURER'S ASSOCIATION

505 Arch Street Philadelphia, Pa.

RESISTANCE WELDER MANUFACTURERS ASSOCIATION • RWMA

MEMBER COMPANIES

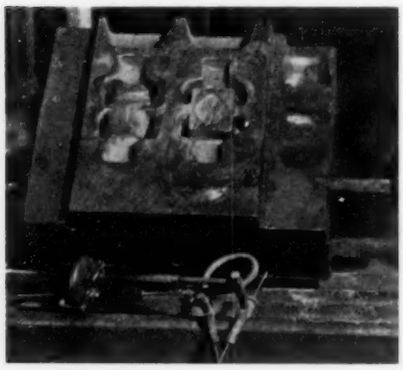
American Electric Fusion Corporation, Chicago, Ill.
Eisler Engineering Company, Newark, N. J.
Expert Welding Machine Co., Detroit, Mich.
Federal Machine and Welder Company, Warren, Ohio
Multi-Hydromatic Welding and Manufacturing Co., Detroit, Mich.
National Electric Welding Machines Co., Bay City, Mich.
Progressive Welder Company, Detroit, Mich.
Swift Electric Welder Company, Detroit, Mich.
Taylor-Hall Welding Corporation, Worcester, Mass.
Taylor-Winfield Corporation, Warren, Ohio
Thomson-Gibb Electric Welding Co., Lynn, Mass.
Welding Machines Mfg. Co., Detroit, Mich.
Acme Electric Welder Company, Los Angeles, Cal.

ASSOCIATE MEMBER COMPANIES

S-M-S Corporation, Detroit, Mich.
Electroloy, Inc., New York City
Welding Sales and Engineering Co., Detroit, Mich.
P. R. Mallory and Co., Indianapolis, Ind.

SAVING DIE COST

Approximately 85% of the cost of a new die was saved when this worn dropforge die was rebuilt with a General Electric atomic hydrogen welder by the Die-Weld Company, Toledo, Ohio. All worn spots



were filled with metal of the same analysis as the die itself (low chrome, high carbon steel), an application for which atomic hydrogen welders are especially valuable. In this particular case, subsequent annealing was not required to permit machining.

WELDING SAVES 30 PER CENT

Three years ago the Welin Davit and Boat Corporation, Perth Amboy, New Jersey, switched from cast and riveted construction to welding for the manufacture of boat davits, and has since saved about 30 per cent in fabrication cost. By test, the company has found welded davits to be somewhat stronger than cast davits of the same size; consequently, the newer welded davits designed to carry a given load are smaller in physical size than corresponding cast or riveted davits.

Photo courtesy Westinghouse Elec. & Mfg. Co.

A Davit Mounted on a Testing Platform. Davits of This Type Are Being Built for Small Passenger-Freight Boats for the Merchant Marine Service. They Are Fabricated from 1/2-Inch and 3/4-Inch Mild Steel. Cheek Plate Is 3/8 Inch and Face Plate Is 1/2 Inch. After Welding, Edges Are Rounded

NEW HOBART TRADE SCHOOL

Officials of the newly incorporated Hobart Trade School, Inc., operated by the Hobart Brothers Company, Troy, Ohio, have announced that plans have been completed for the erection of a new trade school building—a two-story structure with a frontage of 90 feet and a depth of 60 feet. The building will be constructed of all welded steel and can be enlarged at any time there is such a need in the future for expansion. O. H. Menke, president of the trade school stated the new structure will be ready for occupancy by early fall. The new school is expected to provide complete training in machine shop practice, electric arc welding and along other industrial and mechanical lines.

Pictured Is an Architect's Sketch of the New Hobart Trade School Building for Which Completed Plans Have Been Announced. Ground Has Already Been Broken and Construction Is Under Way. Officials State Occupancy Is Expected by Early Fall

WELDING IN NEW HOME OF GARRETT SUPPLY COMPANY

Welding in progress on the new home of the Garrett Supply Company, Los Angeles, Calif., machine dealer. Construction is under the direction of Buttress and McClelland, local contractors. Shop fabrication and field welding was done by Associated Piping & Engineering Company, Ltd.

Photo courtesy General Electric Company

Building Erected by Buttress & McClelland, Local Los Angeles Contractors, Which Has Rigid-Beam-and-Column Steel Frame. Field Welding and Fabrication Done by the Associated Piping & Engineering Co., Ltd. Close-Up View Showing Operator Welding Column at Beam at Left

HIGH PRESSURE PIPE LEAK REPAIRED BY ARC WELDING

To stop a leak in an 8-inch oil pipe-line operating at a pressure of 800 pounds per square inch requires ingenuity.

Photo courtesy General Electric Company

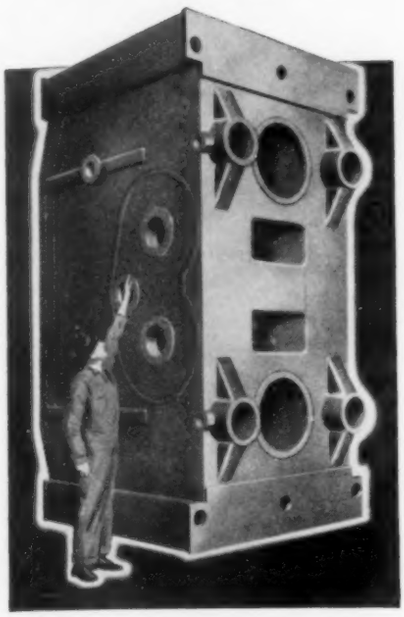
To make the repair, a collar of steel was wrapped around the pipe at a point a little beyond the leak and the ends of the collar were butt welded together. Next, the collar was slipped along the pipe until it covered the leak. To permit the leaking oil to escape without interfering with welding operations, the collar was provided with a tapped drain hole midway between its ends. Upon the completion of both circumferential collar-to-pipe welds, a pipe plug was screwed into the drain and the repair was completed.

WELDING IN STEEL MILL

An helmeted electric welder at work on a section of the 7 1/2-ft. "down-comer" pipe for Republic Steel Corporation's second 1000-ton blast furnace in Cleveland. Note the construction rigging atop the furnace, which is seen in the background, as it neared completion. Now in operation, this furnace gives Republic four furnaces with a capacity of 1000 tons or more.

SIMPLIFY AND SPEED UP CONSTRUCTION

with Welded Rolled Steels



TODAY industry is facing the call for drastic increases in production. Manufacturers everywhere are being asked to swing over to new and unfamiliar products. Time is a vital factor. And to meet this emergency, more and more plants are turning to rolled steel construction—because no other method of fabrication offers the same advantages of speed and economy.

Seemingly impossible jobs can be finished in a hurry with welded rolled steel construction. Time and expense are saved by the elimination of patterns and cores. Designs can be "carpentered in steel" direct from blue prints. "In progress" alterations can be made quickly and easily. The work is half way to completion when you use rolled steel—a thoroughly worked product free from blow holes and other imperfections, ready for immediate fabrication.

Using rolled steel construction puts the entire range of metallurgy's special steels at your disposal. They may be readily combined with one another, or with plain steel or castings, to improve your product, to give it greater strength and less weight, to reduce its cost. Equipment can be designed with its true functional requirements in mind—every part can be made to perform at fullest efficiency.

Are you taking full advantage of the special steels now available? Why not consult a U·S·S engineer on the best ways to use them? His advice and assistance are yours without obligation.

Only 12 days were required *for complete fabrication of this stamping press crown with rolled steel construction. Time saving is one of the many cardinal advantages in the use of rolled steel for machine construction. Immediate execution of the design is possible. There are no delays for parts or patterns. In this case weight was reduced 55%.*

For faster construction and longer-wearing equipment

fabricate with these better steels

U·S·S Cor-Ten — to resist corrosion; to reduce weight or increase strength.

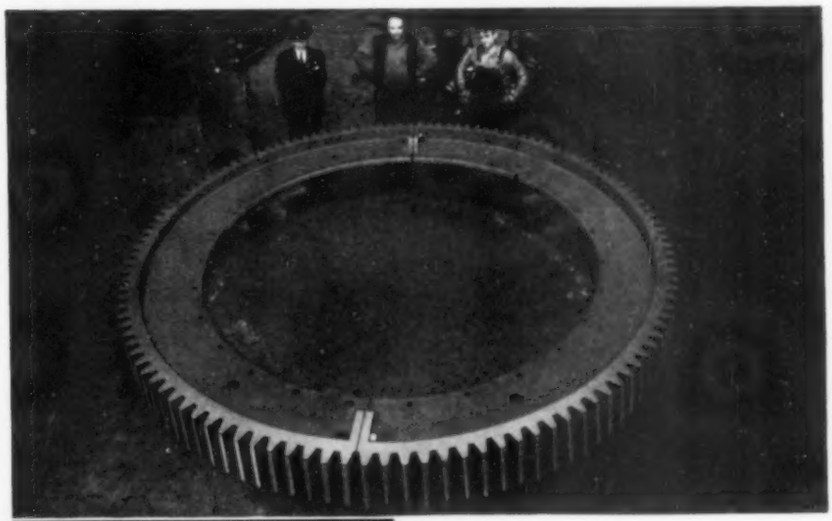
U·S·S Man-Ten — to increase strength without adding weight.

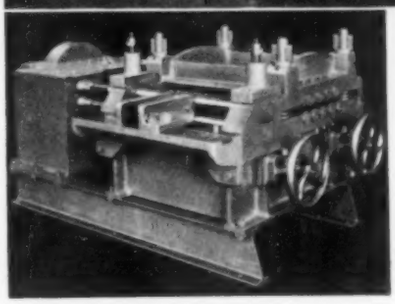
U·S·S Abrasion Resisting Steel—for use where abrasive conditions are exceptionally severe.

U·S·S Heat Resisting Steel —to combat high temperatures.

U·S·S Stainless Steel—to resist corrosion of all kinds.

U·S·S Carilloy Alloy Steels —to carry tremendous bearing pressures.





Completed in one week, *this 11,600 pound gear, with an inside diameter of 9' 11¼", is proof of the speed possible with rolled steel construction. Experience in previous similar jobs showed that it would have required nearly a month to build the same gear with other methods of fabrication.*

• • • •

Time saved 50%. *The Goodman Manufacturing Co., Chicago, Ill. used rolled steel plates and structural sections for all parts of this roller leveler except the top roller housing and front guide portions; cast elements are cast steel. The results were greater strength per unit of weight, 15% saved in weight, 5% saved in cost.*

CARNEGIE-ILLINOIS STEEL CORPORATION, *Pittsburgh and Chicago*
COLUMBIA STEEL COMPANY, *San Francisco*
TENNESSEE COAL, IRON & RAILROAD COMPANY, *Birmingham*
United States Steel Export Company, New York

VISIT THE UNITED STATES STEEL BUILDING USS NEW YORK WORLD'S FAIR · 1940

UNITED STATES STEEL

NEW PRODUCTS

The Society assumes no responsibility for the validity of claims in this Section

FLASHLIGHT EXTENSION

Internal inspection of molds, intricate core castings, and miscellaneous items requiring welding is often hindered because of lack of light in inaccessible places. A new device has been developed to supply light where no ordinary bulb can reach. To inspect the "innards," a flashlight bulb extension is available.

Foundrymen and welders can use it for innumerable purposes. Made in lengths from 6 to 36-in., its plug end is screwed into any flashlight with the bulb in the opposite socket. Being bendable, it can go down into deep recesses or through tortuous passages, and can be positioned exactly where light is most needed without the necessity of holding it. It can be bent to form its own stand.

Known as the Sierra Flashlight Bulb Extension, it is made of special wire encased in high-grade aluminum alloy tubing. It is quite a handy accessory for infinite uses. The new product is manufactured by the Sierra Aircraft Company, Sierra Madre, California.

WELDING SHOP ON WHEELS

A new, two-gun portable spot-welding unit expected to eliminate necessity for duplicate welding equipment and designed for heavy-duty welding requiring high point pressures, large-capacity transformer and adjustable weld-time control for accurate timing is announced by Progressive Welder Company, 3034 East Outer Drive, Detroit, Michigan.

Equipped with floor-saving pneumatic tires for easy portability, the new unit is wheeled from one assembly location to the next as needed, rather than moving the work to the welding equipment.

A low production truck body shop where an entire assembly is completed at one location is one example of the versatility of use of this unit. In this type of work, the unit usually serves a group of welding fixtures used for sub-assemblies as well as occasional assembly line "pinch-hitting." Thus, welding equipment used only for peak rush is entirely eliminated.

The unit illustrated consists of two spot-welding guns, transformer, air-hydraulic pressure booster, weld timer and contractor. Both the push gun (supplied with grounding clamp) and scissors type gun operate from the single transformer mounted in the base of the carriage. Welding point pressures up to 1000 lb. (for the scissors type gun) are supplied by the booster mounted above the transformer and operating from the standard factory air-pressure line. Provision is made to water cool gun jaws and points through individual supply and return lines. Transformer is also water cooled.

SWEAT BANDS

Two new, ruggedly constructed sweat bands, made of fine pore, cellulose sponge securely stitched to a fabricoid band with an inner lining of cork, are announced by the Jackson Electrode Holder Co., Detroit, Mich.

No. 15, photographed in position, is a general purpose band—a perfect safety

No. 15

device for eliminating the hazard of perspiration running into the eyes. It is easily adjusted to the head with a long-lasting $\frac{1}{2}$-in. wide, elastic band.

No. 5, illustrated in the drawing, is intended for use with all Jackson Eyeshields except Types *D*, *D*-6 and No. 25. It is snapped inside the bands without fuss or monkey work.

Both bands are light, cool, comfortable—easily absorb more than fifteen times their weight in moisture. Sanitary, both are quickly cleaned by letting water or any safe, antiseptic solution run through the sponge cellulose. Their efficient design, durable construction and low cost makes them particularly desirable.

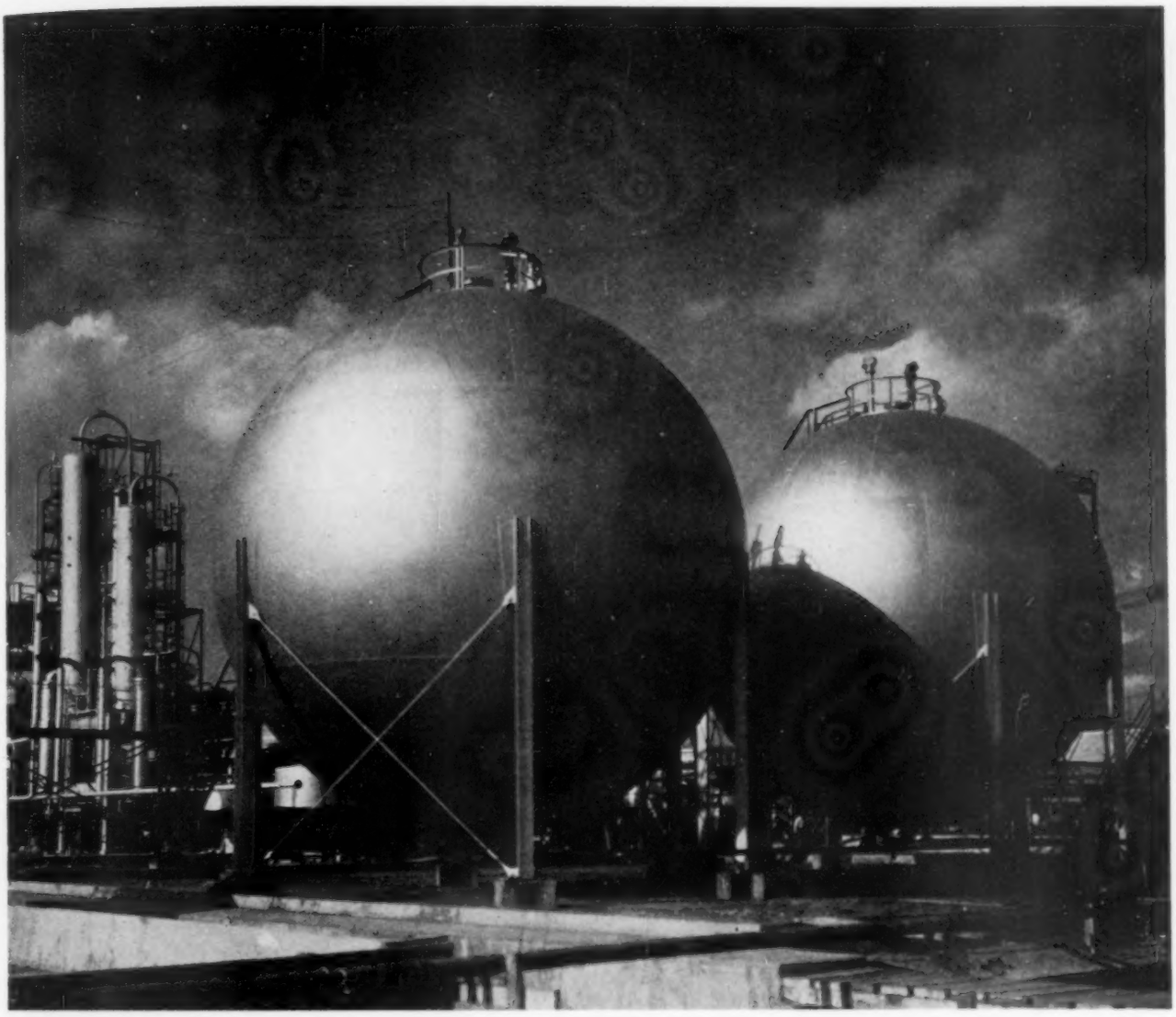
A.C. ARC WELDERS

Ergolyte Welders, manufactured by the Ergolyte Manufacturing Company of 3644 Lawrence Street, Philadelphia, offer new convenience in welding. All controls and sockets have been brought into full view on a sloped panel, eliminating the necessity for crouching or squatting to select heats or make adjustments. Heats may be selected in gradual steps over a wide range, correctly proportioned to correspond to the commercial gages of metal handled. Insulation is double spun glass.

MULTIPLE WELDING SERVICE

A new paralleling arrangement to combine the capacities of two or more P&H-Hansen WD-150 welders has been developed by the Harnischfeger Corporation of Milwaukee. With this new parallel hook-up, an operator has at his disposal the aggregate current of two or more machines for peak loads. When the connection is "cut," each machine can be used separately by individual operators—doubling or tripling welding production. Sets of two or more WD-150 welders are obtainable for parallel operation. Their square frame design enables them to be stacked one above the other without special structural framework.

On the WD-150 welder current selection is accomplished by a single control, the generator automatically responding with the desired current. With this new



SPHERICAL TANKS

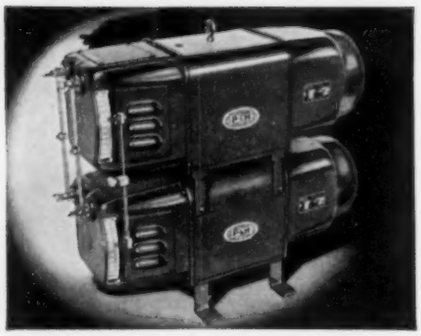
. . . of welded construction

Welding gives these spheres a smooth, pleasing appearance. However, there are other benefits derived from welding these vessels that are more important. For instance, a great deal of material is saved by the elimination of heavy inside and outside butt-straps. Every joint is accurately fitted-up before welding begins, and when it is finished each seam is permanently gas-tight. Painting and maintenance costs are cut to a minimum. These spheres are 35 ft. 3 in. in diameter. They hold 4,000 Bbls. of butane with a working pressure of 100 lbs. per sq. in.

CHICAGO BRIDGE & IRON COMPANY

Chicago	2455 Old Colony Bldg.	Birmingham	1507 North 50th Street	Philadelphia	1668-1700 Walnut St. Bldg.
New York	3398-165 Broadway Bldg.	Tulsa	1654 Hunt Bldg.	Boston	1565 Consolidated Gas Bldg.
Cleveland	2282 Rockefeller Bldg.	Houston	2919 Main Street	San Francisco	1097 Rialto Bldg.
Dallas	1489 Liberty Bank Bldg.	Detroit	1556 Lafayette Bldg.	Los Angeles	1455 Wm. Fox Bldg.

Fabricating plants in CHICAGO, BIRMINGHAM, and GREENVILLE, PA.



Two P&H-Hansen WD-150's with Parallel Hook-Up

paralleling device, the single current control is carried over to the combined machines. The selector of each machine is connected to that of its fellow machines by means of a "multiple shifter," which, when set for a given current, automatically sets the connected machines at that amperage. Thus, for a current of 375 amperes using three machines, the "multiple shifter" is set at 125 amperes, automatically setting all the machines at that figure, and producing a resultant current of 375 amperes.

When the machines are to be operated as separate units, the wing nut on the connecting rod of the "multiple shifter" is loosened, disengaging the rod and enabling individual current settings to be made on each machine.

Single or multiple units are available with stationary or portable mountings. For further information on the P&H-Hansen WD-150 square frame arc welder and the parallel hook-up, address the Harnischfeger Corporation, Milwaukee, Wisconsin.

AC HARD-FACING ROD

Stoody Company, manufacturers of hard-facing rods, announce the development of Stoody AC, a new hard-facing alloy.

Stoody AC, as its name indicates, was designed especially for application by alternating current welding machines. This new electrode flows freely under the arc, produces very little spatter and forms a hard, tough, wear-resistant deposit.

According to the manufacturers, Stoody AC is suitable for all types of applications requiring an AC hard-facing electrode. It is available in three rod sizes: $^1/_8$ x 14 inches, $^5/_{32}$ x 14 inches and $^3/_{16}$ x 14 inches.

NEW ELECTRODE PAMPHLET

An entirely new pocket-size pamphlet covering the Murex line of electrodes for arc welding has just been published by the Metal & Thermit Corporation, 120 Broadway, New York, N. Y. The new pamphlet gives complete data on physical properties, chemical analysis, qualifications, approvals and recommended procedures for all Murex mild steel welding electrodes, as well as similar but briefer information on Murex alloy steel electrodes. Copies may be had on request to the manufacturer.

REJECTS AND MAINTENANCE REDUCED BY GUN WELDERS

Because they speed assembly, give a stronger bond and reduce rejects to a minimum, 17 electronically controlled gun welders have replaced former methods to assemble automobile bodies in some plants. In one modern radiator and grill assembly department, each of six gun welders joins 20 separate parts at 150 places in less than a minute. Because the gun-welded bonds are stronger, only half as many welds are used. The electronic control developed by Westinghouse engineers prevents burned spots, reduces rejected assemblies to a minimum and requires no maintenance.

Twenty Separate Pieces to Form a Radiator and Grill Assembly Are Placed in the Jig by Workmen. The Jig Is Swung Around and Gun Welders Average the Necessary 150 Spots in Less Than 60 Seconds. Six of the New Westinghouse Electronically Controlled Gun Welders Are Used in This Department

The Two Electronic Tubes Shown in the Open Cabinet So Accurately Control the Flow of Current to the Gun Welders That Burned Spots Are Prevented. Having No Mechanical Contacts, No Maintenance Is Required. This Is a Typical Battery of Westinghouse Electronic Control for Welders

Spot, projection, flame and arc welding were all previously used. Conventional spot welding was particularly troublesome, producing burned spots and poor bonds. Appreciable work had to be repaired, and at times burns were so bad the parts were scrapped, especially body parts like fenders and cowls. Costly shutdowns and heavy maintenance were common due to burned contacting devices.

These gun welders were designed by engineers of the Progressive Welding Company.

WELDING CATALOGUE

"Airco Electric Welding Products," a 32-page illustrated booklet, just issued by Air Reduction, describes the complete line of Airco electrodes and Wilson electric welding machines.

The booklet discusses various types of electrodes and offers suggestions as to where each type can be used to best advantage. Included in the description of each electrode is (1) a general description; (2) suggested applications; (3) welding procedure; (4) physical properties; (5) specification table.

Another section of the catalogue is devoted entirely to electric welding accessories. Among the items covered are aprons, brushes, cable, graphite electrodes, face shields, leather gloves, goggles, helmets, electrode holders and many others. The products in this section are conveniently arranged for quick reference.

A page of excerpts from "Welding Symbols and Instructions for Their Use," as published by the AMERICAN WELDING SOCIETY, is another feature included in the booklet.

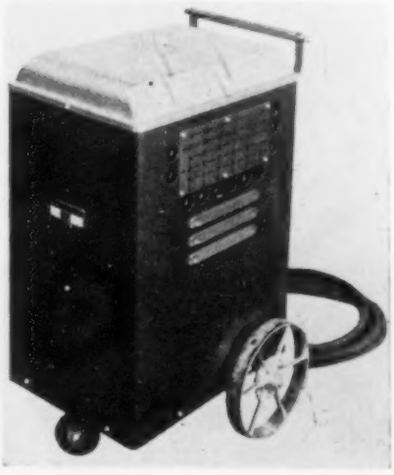
The concluding section offers a detailed discussion of various Wilson electric welders. The "Hornet," "Yellow Jacket," Model MCT and Model GA are the welders so described.

Copies of this catalogue, No. 103, can be obtained by writing Air Reduction, 60 East 42nd Street, New York, N. Y.

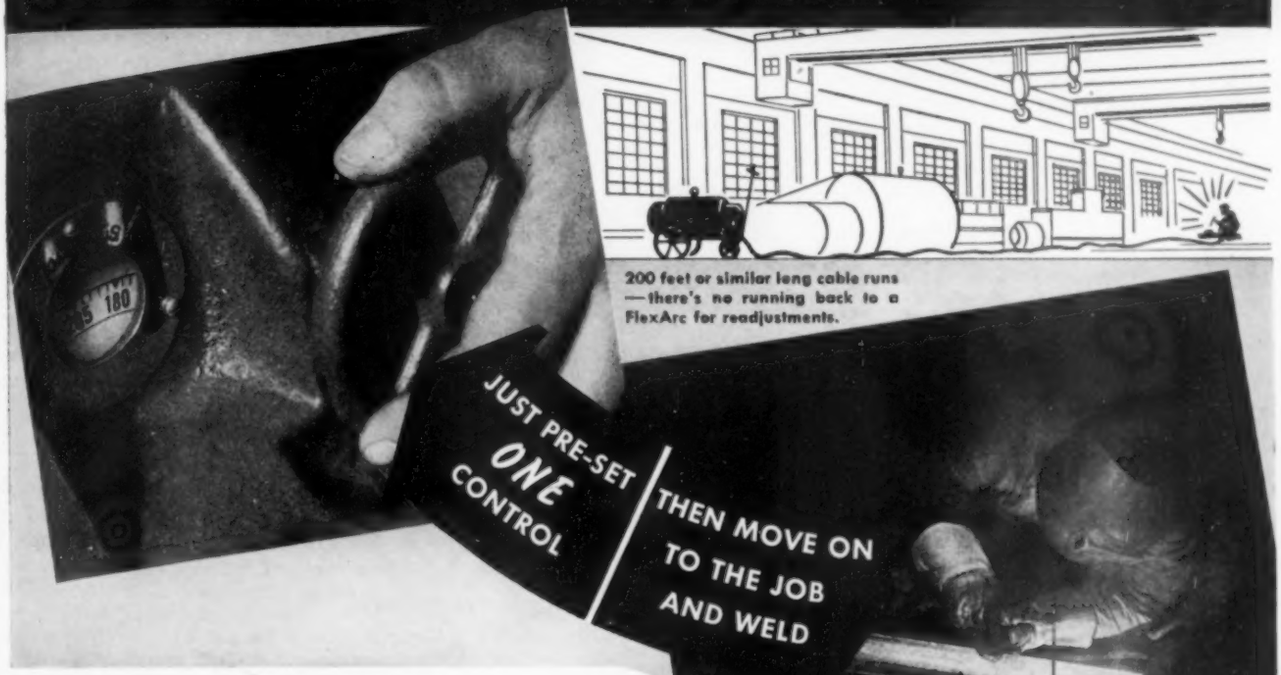
AC ARC WELDER

A new modern all-purpose portable ac welder designed for all around general utility service and production welding of every type, has just been announced by the Westinghouse Electric & Manufacturing Company. Standard models operate on either 220 or 440 volts, are completely self contained, and incorporate several distinct new design features.

From 20 to 250 amperes of welding current is available in twenty-seven current steps, with increments properly proportioned to meet the needs of welding with a wide variety of electrode types and



If You're "From Missouri" Make The FLEXARC 200-FOOT TEST



200 feet or similar long cable runs —there's no running back to a FlexArc for readjustments.

It's performance that counts in any welder! That's why Westinghouse invites you to stop in at your dealer's today and make the FLEXARC 200-FOOT TEST. You'll quickly see why this is the welder you should have on *your* job.

Maybe you think you've had a constant arc before. Then wait until you experience the rock steadiness of the FlexArc! See how current readjustments after warm up really are unnecessary with this modern machine. Watch FlexArc's *automatic* control keep the arc exactly right for every weld position, permitting you to stay on the job and weld.

If you don't find new freedom from gadgets and arc adjustments—if you don't weld faster and better, we miss our guess. Make the test today—there's no obligation—you'll get a new slant on arc welding.

WESTINGHOUSE ELECTRIC & MFG. CO.
DEPT. 7-N EAST PITTSBURGH, PA.

J-21066

RENT A FLEXARC AND GIVE IT AN ON-THE-JOB TEST

Here's a real showdown! Rent a FlexArc. Easy terms—no obligation to buy. Rental can be applied against purchase price.

Westinghouse Flexarc Welders

diameters. Current adjustment is easy; just select the current desired, insert the bayonet plugs in the proper receptacles and the machine is ready to weld. Current values are clearly indicated in large legible numerals.

Safety is well provided for. A built-in "De-Ion" breaker insures protection against long sustained overloads, such as might occur by accidently leaving the machine short circuited. This is convenient, too, for disconnecting the machine from the line without having to go back to a service or feeder switch. Open circuit or striking voltage is exceptionally low, being on the order of 80 volts at twenty amperes, and ranging down to 50 volts at the highest current rating.

ALL PURPOSE A.C. WELDER

A new four-page illustrated leaflet describing the Type WT-4 portable modern a.c. welder, designed for all-around general utility service and production welding, has just been announced by the Westinghouse Electric & Manufacturing Company. These welders have a range of from 20 to 250 amperes and work off of 220 or 440 volt a.c. current.

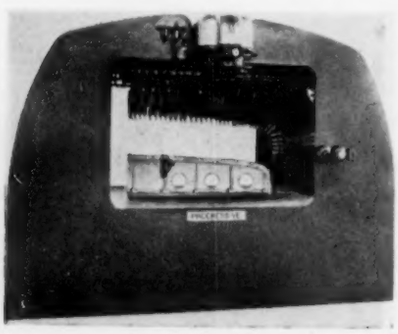
The leaflet contains a description of the unusual features of this newly developed welder: its unique current adjustment scheme, with 27 current steps; its safety features, including low open circuit voltage and built-in circuit breaker protection. Illustrations of the different parts aid the descriptions.

Copies of catalog section 26-325 may be obtained from Dept. 8N48, Westinghouse Electric and Manufacturing Co., East Pittsburgh, Pa.

HIGH SPEED SPOT WELDER

Details of its new "Progress-O-Matic" high speed spot welder capable of making upward of 6000 spot welds per hour have been announced by Progressive Welder Company, 3034 East Outer Drive, Detroit, Michigan. Said to produce better welds than possible with conventional welding equipment of even lower production capacity, the first production machine is now in operation on 1941 model automobile body work.

An entirely new method of current transfer which makes and breaks the secondary as well as the primary circuit, gives the machine such flexibility of operation that it can weld an assembly having several thicknesses of metal.



With the new design, all welding points are brought down on the work under full pressure and held there throughout the entire welding cycle. To this is attributed, mainly, the obtaining of better welds even with its more rapid operation. Since points are already on the work before the current is "on" and remain there after the current is "off," chance of burned welds is virtually eliminated. A longer cooling time, with work under pressure between contacts, further assists in improving weld characteristics.

New machine is provided with quickly interchangeable lower electrodes to accommodate different size assemblies. The machine illustrated makes 36 spots to join the two halves of two sizes of automobile hood tops.

In operation, each hood top half is loaded into the machine—from front and back, respectively. Operator then touches the control button to raise the work to welding position. This is accomplished through four air cylinders. At the end of their stroke an automatic valve is tripped and additional cylinders superimpose a "wedging" support for the central portion of the work table. All welding points are thus effectively brought up to the desired pre-determined pressure.

The machine thus automatically begins its welding cycle. When completed, the table returns to open position and the work is unloaded through one end of the machine.

WELDED BOILERS

More than a mile and a half of arc welding was involved in construction of these three boilers which are over fifteen feet high and weigh more than twenty tons. Oil City Tank and Boiler Company, Oil City, Pennsylvania, who built them for the Glenside Housing Project at Reading, Pennsylvania, claims that they are the world's largest steel firebox boilers according to experienced boiler engineers.

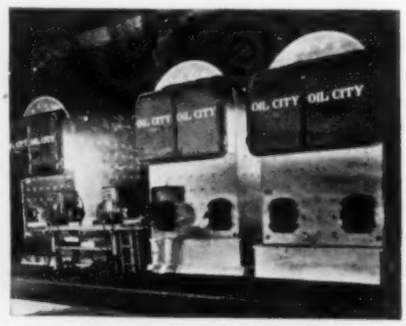


Photo courtesy The Hobart Brothers Co.

ANG-LITES

"Ang-Lites" are the industrial diagnostic lites manufactured by Dr. D. L. Weiss of New York City.

"Ang-Lites" are expressly designed to bring brilliant lite at various angles to deeply recessed areas where careful inspection is necessary and desirable, thus speeding up work.

"Ang-Lites" are fabricated from Lucite (Du Pont) and are practically unbreakable, are hand tooled, carefully tested and inspected and should not be confused with the moulded product.

"Ang-Lites" are made in various stock shapes and designs with $^3/_8$, $^1/_2$ and $^5/_8$ inch diameter at the threaded end. Lite can for instance be brought around 180 degrees into almost inaccessible places, and for retrieving wires, etc., the hooked "Ang-Lite" will be found almost indispensable. One of the distinctive features of the Ang-Lites is that some of the models can be equipped with the powerful "Alnico" magnet. Special forms can be made up to order.

The handle of the "Ang-Lite" unit is a specially designed (Eveready) pocket pen lite with a telescopic metal sleeve which shields the lite source and contains reducing bushings into which are screwed the large selection of interchangeable "Ang-Lites." When in operation there is approximately 50–75 candlepower of lite at the point or tip, varying with the length and degree of the angle, with little or no lite along the shaft.

AIRCO ANNOUNCES APPOINTMENT

Mr. Howard R. Salisbury has been appointed manager of the Air Reduction Company at Philadelphia. Mr. Salisbury has been connected with Airco for fifteen years. He was manager of Airco at Bettendorf, Iowa, for two years and assistant manager at Philadelphia for the past six

Howard R. Salisbury

years. He is also a past-chairman of the Philadelphia Section of the AMERICAN WELDING SOCIETY. Mr. Salisbury succeeds Mr. William W. Barnes, retired.

Mr. H. B. Seydel, formerly assistant sales manager of the New York District, has been appointed assistant manager at Philadelphia.

Annual Meeting
October 20-25, 1940

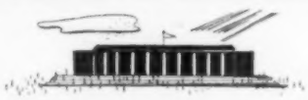
SELLING IS *Easier*

THE METAL EXPOSITION WAY!

Why? . . . because the best prospects in the metal industry *come to you* at the National Metal Exposition. Come, eager to see what's new in their field . . . to inspect materials and equipment in actual operation . . . to compare . . . to analyze . . . and to *buy!*

These men are the cream of purchasing power in your field. Last year's 33,000 registration included a high percentage of Presidents . . . Vice-Presidents . . . Treasurers . . . Managers . . . Metallurgists . . . Engineers . . . Superintendents . . . Chemists . . . Purchasing Agents—men who specify and buy every type of metal product.

More manufacturers than ever before will exhibit in this year's National Metal Exposition at Cleveland. There are still plenty of choice spaces left at the regular $1.00 per sq. ft. rate. Write or wire collect today for floor plan and full information. Address: W. H. Eisenman, Managing Director, National Metal Exposition, 7301 Euclid Avenue, Cleveland, Ohio.



BIGGEST IN HISTORY!

Over 275 leading manufacturers have already reserved 90,000 square feet of exhibit space . . . making the 1940 National Metal Exposition the largest in the 22 years it has been managed by the American Society for Metals . . . proof that more and more companies find selling easier the Metal Exposition Way.

STRATEGIC LOCATION!

Cleveland is the hub of the most diversified manufacturing district in the country . . . home of many famous industrial organizations . . . easily accessible from all parts of the country . . . ample convention facilities . . . a city in which many successful Metal Expositions have been held.

GUARANTEED ATTENDANCE!

Four national engineering societies: American Society for Metals; American Welding Society; The Wire Association; and Iron & Steel Division and Institute of Metals Division, American Institute of Mining & Metallurgical Engineers . . . hold their annual Metal Congress in conjunction with the Metal Exposition . . . assuring the highest type attendance.

NEW AIDS TO PRODUCTION!

If you have a new aid to production . . . a better metal . . . a faster machine—your business demands representation with other leading companies at the Metal Exposition because buyers for every big industry will be shopping there. Get your share of the rush business ahead . . . exhibit at the Metal Exposition!

The WORLD'S GREATEST EVENT IN THE METAL INDUSTRY 70% NEW ATTENDANCE EACH YEAR

NATIONAL METAL EXPOSITION

AND METAL CONGRESS

OCTOBER 21-25, 1940 *Cleveland, Ohio*

MANAGED BY AMERICAN SOCIETY FOR METALS

» » » SECTION ACTIVITIES « « «

CINCINNATI

The annual meeting of the Cincinnati Section was held June 12th and the following officers were elected:

Chairman, Eric O'Hars, Cincinnati Gas & Elec. Co.

Vice-Chairman, W. A. Maddox, Cincinnati Milling Machine Co.

Treasurer, Lewis B. Blakeney, Westinghouse Elec. & Mfg. Co.

Secretary, R. G. Fugate, Williams and Co., Inc.

Directors for two years, Carl P. Bartels, R. S. Diserens, J. K. Ross.

Members still serving on Executive Committee: R. L. Kirby, G. F. Lockeman, F. L. Meacham.

A good attendance was on hand and everyone thoroughly enjoyed an air travel film presented under the auspices of American Airlines. An interesting event of the evening was the presentation of a leather briefcase by Eric O'Hara to J. R. Bergman for getting the most new members during the Section's membership drive.

LOS ANGELES

The regular meeting of the Los Angeles Section was held June 20th on the Sky Deck of the Sky Room, Union Air Terminal, Burbank. There were approximately 260 members and guests at the dinner meeting.

Mr. Lorenzo Kennon gave a talk on the "Development of Resistance Welding," which was followed by a paper given on the "Value of Research in Resistance Welding" by Harry L. Chiles, Production Resistance Welding Engineer at Lockheed Aircraft Corp.

Due to the chilly evening on the roof, the meeting was adjourned to Lockheed Aircraft Hangar at the Union Air Terminal, where inspection was made of the several large planes, and a motion-picture film on "Resistance Welders" was given by courtesy of Taylor Winfield Company.

NEW YORK

The Executive Committee of the New York Section held a meeting on the afternoon of June 18th. The chairman appointed the following committee chairmen: *Program*, E. V. David; *Lecture Course*, S. S. Scott; *Membership*, R. E. Bedworth; *Activities*, G. Schneider; *By-Laws*, J. B. Tinnon; *Budget*, C. Kandel.

Mr. E. Von Steeg was appointed chairman of a new committee on the training of operators with instructions to make a survey of existing facilities for the purpose within the territory of the New York Section and bring in recommendations for meeting the needs for additional trained operators likely to be needed in connection with national defense.

NORTHERN NEW JERSEY

At the June 6th meeting of the Executive Committee of the Northern New Jersey Section, the following committee appointments were made.

Membership: T. B. Smith, *Chairman;* G. J. Blind, J. Gunning, A. G. Scherrer, L. W. Payne, F. H. Andrews, D. C. Ogilvie, M. F. Sheely, J. J. Manning, Alex Katchen, R. McPeek.

Program: Alexander Kidd, *Chairman;* R. E. Powell, G. M. Deming, F. B. Swankhous, R. Jewett, J. J. Gaffney, O. W. Fisher.

Educational: M. F. Sheely, *Chairman;* G. W. Nigh, E. F. Humm, R. M. Wilson.

The Committee voted to sponsor a summer outing for members and friends, to be held Saturday, September 7th. Complete details will be announced later.

ST. LOUIS

The annual installation of officers and party was held Friday, June 14, 1940, at the York Hotel with 248 members and guests present. The officers are:

Chairman, L. H. Dodd, American Institute of Steel Construction.

Vice-Chairman, H. H. Scheaff, Combustion Eng. Co.

Secretary, M. B. Scioletich, Combustion Eng. Co.

Treasurer, A. S. Schwarz, John Nooter Boiler Works Co.

Directors: A. Allina, Lockwood Hill, W. G. Hooper, N. F. Moss, M. E. Meyerson, R. J. Ryan.

An excellent dinner and elaborate floor show climaxed the most successful season of the St. Louis Section.

YORK-CENTRAL PA.

On June 12th the York-Central Pennsylvania Section held its last regular monthly meeting of the season. About 80 members assembled on a warm summer night to hear George A. Jessop, Chief Engineer of the S. Morgan Smith Company, speak on "Economic Production of Heavy Welded Parts." His talk was well illustrated with interesting slides and covered the different phases of shop production and methods used in fabrication.

After the address and question period a very excellent buffet lunch was served by a committee headed by Oscar Weber. It was announced that the first fall meeting of the Section would be held in September and that the Program Committee was planning a big dinner meeting to celebrate the first anniversary of the Section.

List of New Members

June 1st to June 30, 1940

BOSTON

Weissinger, Walter F. (C), 10 Jeppon Ave., Worcester, Mass.

CINCINNATI

Tesmer, A. W. (C), American Rolling Mill Co., Fabricating Div., Middletown, Ohio.

CLEVELAND

Struven, Albert L. (B), Arthur G. McKee & Co., 2422 Euclid Ave., Cleveland, Ohio.

Tiegiser, James E. (C), 9522 Bessemer Ave., Cleveland, Ohio.

CONNECTICUT

Mac Fayden, Malcolm (B), New England School of Prac. Train., 691 Conn. Blvd., E. Hartford, Conn.

DETROIT

Hecker, Carl L. (C), 678 Henley Dr., Birmingham, Mich.

Newman, Clarence A. (C), 9950 Memorial Ave., Detroit, Mich.

LOS ANGELES

Grohs, Fred (D), 2719 Missouri Ave., South Gate, Calif.

Johnston, C. W., (D) 4411 E. 59th Place, Maywood, Calif.

Karnes, N. J. (C), 3745 Randolph, Huntington Park, Calif.

Lutz, Everett (C), Anderson Equip. Co., 644 E. Florence Ave., Los Angeles, Calif.

Pickarts, J. D. (C), 6239 Hillandale Dr., Los Angeles, Calif.

Santini, Robert (B), Carmel Hotel, Santa Monica, Calif.

Sciaky, Mario (B), Sciaky, Inc., 11001 Cottage Grove Ave., Chicago, Ill.

MARYLAND

Schlining, Charles (D), 2613 Georgetown Road, Baltimore, Md.

MILWAUKEE

Gilson, H. B. (C), Linde Air Products Co., 732 First Wisconsin Nat. Bank, Milwaukee, Wis.

NEW YORK

Akers, Arthur W. (C), Technicians Inst.,

244 W. 14th St., New York, N. Y.
Bell, John J. (C), Robins Dry Dock Co., Ft. of Dwight St., Brooklyn, N. Y.
Dunn, William J. (C), Combustion Engrg. Co., 200 Madison Ave., New York, N. Y.
Goldstein, Arnold (D), 267 Stanton St., New York, N. Y.
Gronquist, Walter (D), 151 E. 123rd St., New York, N. Y.
Jugovich, Michael (D), 309—3rd St., Hoboken, N. J.
Krause, George E. (D), 47-10 Laurel Hill Blvd., Woodside, L. I., N. Y.
Miller, Ralph E. (B), 1349 Lexington Ave., New York, N. Y.
Rottman, Wm. A. (D), 8660—91st St., Woodhaven, L. I., N. Y.

NORTHERN NEW JERSEY

Blenckstone, F. E. (C), National Cylinder Gas Co., 998—39th St., North Bergen, N. J.
Boschen, H. C. (C), National Cylinder Gas Co., 998—39th St., North Bergen, N. J.
Noakes, J. F. (C), National Cylinder Gas Co., 998—39th St., North Bergen, N. J.
Phillimore, Horace (D), 1301 Washington St., Hoboken, N. J.
Sigrist, Robert F. (D), 70 Burnett St., Newark, N. J.
Trela, Peter (C), Trelas Welding Shop, 14 Columbia Ave., Passaic, N. J.

WESTERN NEW YORK

Wustrack, Paul O. (D), Ramapo Ajax Div., American Brake Co., Niagara Falls, N. Y.

SAN FRANCISCO

Cunningham, Jack (B), Lincoln Elec. Co., 866 Folsom, San Francisco, Calif.
Hoag, L. Frank (B), 114 Irvington St., San Francisco, Calif.
Horn, N. B. (D), 380 Elm Ave., San Bruno, Calif.
Huhn, James M. (D), P. O. Box 526, South San Francisco, Calif.
Johnson, Pete C. (C), 830 Victoria St., San Francisco, Calif.
Kremer, Eugene C. (C), 721 Miller Ave., South San Francisco, Calif.
Patterson, Cecil B. (C), 533 Park Way, South San Francisco, Calif.

WICHITA

Denison, Harold M. (C), Kansas Gas & Elec. Co., Sedgwick Bldg., Wichita, Kansas.

YORK–CENTRAL PENNA.

Shook, Edward C. (C), % C. Hendricks, R. F. D. 1, Hallam, Pa.

NOT IN SECTIONS

Buchkoe, Raymond J. (C), State House of Correction & Branch Prison, Marquette, Mich.
Warren, William B. (B), Box 267, Pascagoula, Miss.

EMPLOYMENT SERVICE BULLETIN

SERVICES AVAILABLE

A-364. Research Engineer desires position. Had 10 years' experience as metallurgical chemist and 4 years as production superintendent and research engineer. Graduate Chemical Engineer. Seeks position as production engineer or research.

A-365. Combination welder with commercial and technical education relating to welding, desires position leading to Sales Engineer in hard-surfacing field. Has sales experience and fair knowledge of hard-surfacing principles and applications.

A-366. Electric Welder desires position. Attended Haller School of Welding. Has had some shop work. Would like position as third-grade welder or tacker. Twenty-nine years of age.

A-367. Arc Welder and Gas Cutter. Graduate Lincoln and Smith factory schools. One month shop-welding experience. Can read blueprints. Age 25. Go anywhere.

INSPECTORS OF AERONAUTICAL MATERIALS SOUGHT BY NAVY DEPARTMENT

In connection with the national defense program the United States Civil Service Commission has announced an open competitive examination to fill inspector positions, in the field of aeronautical engineering, in the Navy Department. The examination covers three grades, with salaries ranging from $1800 to $2600 a year, less a retirement deduction of $3\frac{1}{2}$ per cent. Applications will be rated as received at the Commission's Washington office until further notice.

Applicants must have had experience in the inspection or testing of aeronautical engineering materials to determine compliance with specifications or standards of manufacture; or in the inspection or testing of aircraft engines and their accessories for the same purposes. Substitution of experience as aircraft mechanic or aviation engine mechanic, or of engineering study in an accredited college, may be allowed for part of the specified experience. Applicants will not be given a written test, but will be rated on the qualifications shown in their applications, and on corroborative evidence.

Full information as to the requirements for the examination, and application forms, may be obtained from the Secretary of the Board of U. S. Civil Service Examiners at any first- or second-class post office, or from the United States Civil Service Commission, Washington, D. C.

UNITED STATES CIVIL SERVICE EXAMINATIONS

Senior inspector, engineering materials (aeronautical), $2600 a year; inspector, engineering materials (aeronautical), $2000 a year; junior inspector, engineering materials (aeronautical), $1800 a year, Navy Department (for duty in the field wherever assigned).

Applications will be rated as received until further notice, and certification made as the needs of the service require, except that if sufficient eligibles are obtained, the receipt of applications may be closed, in which case due notice will be given.

CIVIL SERVICE EXAMINATION TO BE HELD FOR METALLURGISTS AND METALLURGICAL ENGINEERS

In connection with the national defense program the United States Civil Service Commission is endeavoring to secure well qualified metallurgists and metallurgical engineers for employment in the Federal Government. Examinations have been announced to fill these positions, covering six grades, with salaries ranging from $2000 for the junior grades to $5600 for the principal grades. The salaries are subject to a retirement deduction of $3\frac{1}{2}$ per cent.

Applications must be filed with the Commission's Washington office not later than August 22nd if received from States east of Colorado, and not later than August 26, 1940, if received from Colorado and States westward.

Applicants must have completed a 4-year college course with major study in chemistry, physics, engineering or metallurgy. In addition, except for positions in the junior grade, they must have had professional experience in some branch of metallurgy or metallurgical engineering. The length and difficulty of the experience vary according to the grade of the position. Applicants for the junior grades need not have had experience in metallurgy or metallurgical engineering if their college degree was received in either of these fields, or if they completed certain college study supplemented by courses in strictly metallurgical or metallurgical engineering subjects. Applicants will not be given a written test, but will be rated on their qualifications as shown in their applications and on corroborative evidence.

Further information as to the requirements for the various grades, and application forms, may be obtained from the Secretary of the Board of U. S. Civil Service Examiners at any first- or second-class post office, or from the U. S. Civil Service Commission, Washington, D. C.

SAFETY AWARDS

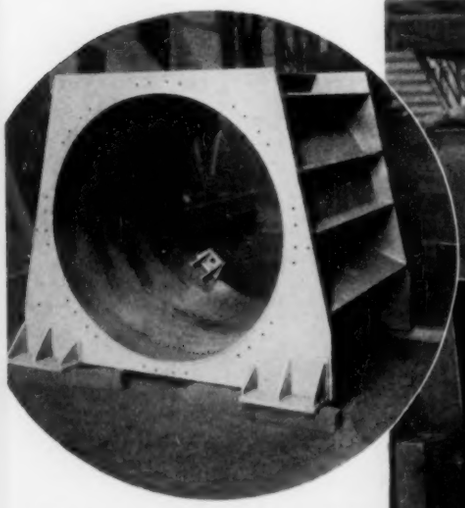
Fifteen safety awards have been won by employees of the Standard Oil Company of Indiana from the American Petroleum Institute, President, Edward G. Seubert of Standard announced Aug. 1st.

Each award recognized success in preventing accidents in a different branch of operations for 1,000,000 or more man hours without loss of time or disabling injury because of accident.

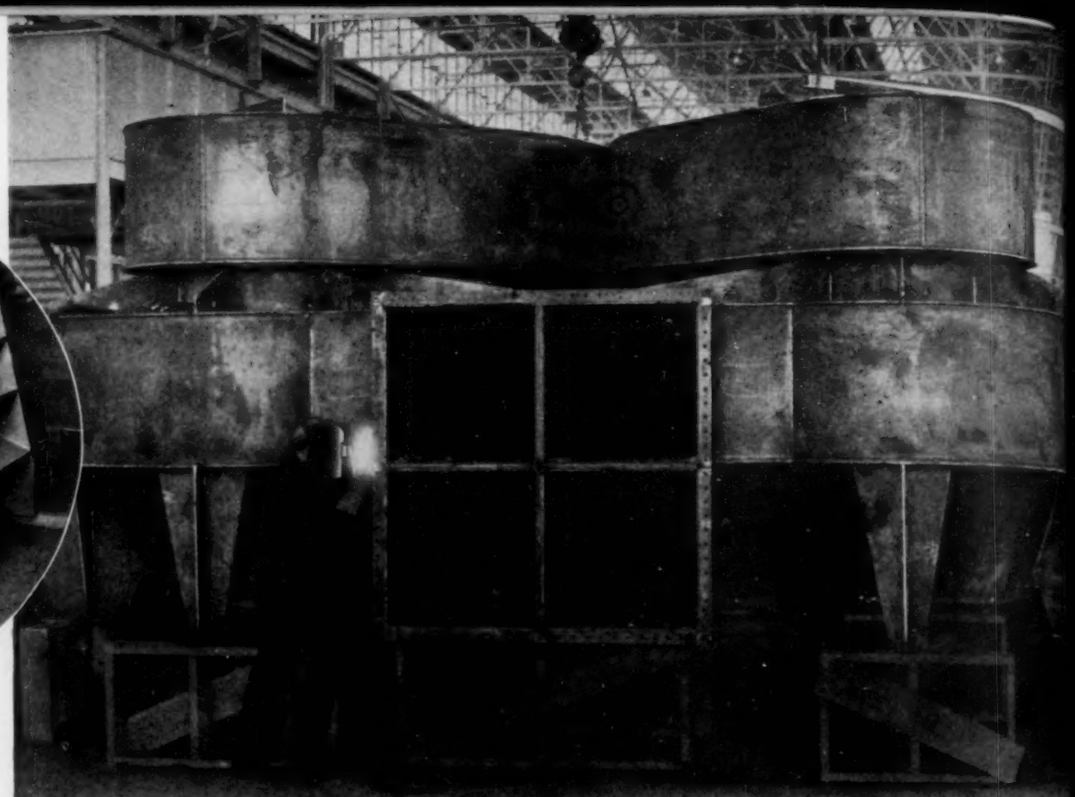
Eleven of the awards were won by employees in the Standard refinery at Whiting, Ind., the largest complete refinery in the world and holder of the world's safety record for refineries.

They were for the tin shop which has worked 19 years without a single accident and has had an average of 45 employees, electric department for 11 years with an average of 65 employees, light oil finishing department for $10\frac{1}{2}$ years with an average of 60 employees, candle department for $7\frac{3}{4}$ years with an average of 75 employees, *welding department for 7 years with an average of 100 employees* and a number of other departments.

Dust collectors Murex-welded by American Blower Co., Detroit, involve many Fillex applications.



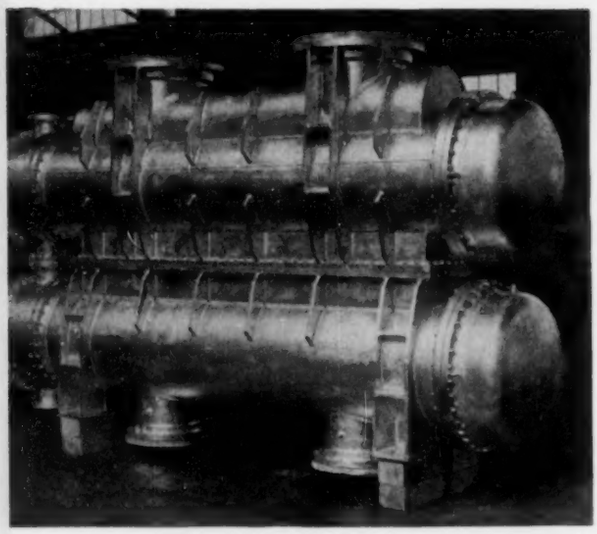
Fillex speeds fillet welding like that in this air test assembly, Murex-welded by The Graves-Marshall Co., Dayton, O.



YOUR HORIZONTAL FILLETS WILL COST LES

made with **FILLEX** *the heavy coated* **"HOT ROD"** *that provide cleaner welds at higher currents*

Fillets in these Murex-welded petroleum condensers, built by Ross Heater Co., Buffalo, are typical of those made with Fillex.



- Specially designed for high speed horizontal fillet welding, Murex Fillex Electrodes can help appreciably in reducing your welding costs.

Even at very high amperages, Fillex Electrodes produce sound, evenly proportioned fillets without undercutting and with a minimum of spatter. Slag is easily removed, resulting in real savings in time on multi-pass work. Weld surfaces are exceptionally smooth and welds require little or no cleaning.

Write and ask to have Fillex demonstrated on your horizontal fillet welding applications. Our nearest branch or distributor will gladly send a representative. No obligation, of course.

METAL & THERMIT CORPORATION, 120 BROADWAY, NEW YORK, N. Y.

Albany • Chicago • Cincinnati • Detroit • Minneapolis • So. San Francisco • Toronto

"Murex Electrodes—Thermit Welding—Thermit Metals & Alloys."

Investigate Thermit Welding, too—in use since 1902 for heavy repair work; crankshafts, housings, frames, etc.

MUREX HEAVY COATED *Electrodes*

A COMPLETE LINE FOR EVERY WELDING APPLICATION